LECTURES

ON

MOLLUSCA;

OR

"SHELL-FISH" AND THEIR ALLIES.

PREPARED FOR THE

SMITHSONIAN INSTITUTION,

BY

PHILIP P. CARPENTER, B. A., PH. D.,

OF WARRINGTON, ENGLAND.

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Who has not admired the beauty of shells?—the rich luster of the Cowries; the glossy polish of the Olives; the brilliant painting of the Cones; the varied layers of the Cameos; the exquisite nacre of Mother-of-pearl? Who has not listened to the mysterious "sound of the sea" in the Whelks and Helmets, or wondered at the many chambers of the Nautilus? What child ever went to the sea shore without picking up shells; or what lady ever spurned them as ornaments of her parlor? Shells are at once the attraction of the untutored savage, the delight of the refined artist, the wonder of the philosophic zoologist, and the most valued treasures of the geologist. They adorn the sands of sea-girt isles and continents now; and they form the earliest "footprints of the sands of time" in the history of our globe. The astronomer, wandering through boundless space with the grandest researches of his intellect, and the most subtle workings of his analysis, may imagine, indeed, the history of past time and speculate on the formation of globes; but his science presents us with no records of the past. But the geologist, after watching the ebb of the ocean tide, examines into the soil on the surface of the earth and finds in it a book of chronicles, the letters of which are not unknown hieroglyphics, but familiar shells. He writes the history of each species, antedating by millions of years the first appearance of man upon this planet, the abrasion of the Mississippi Valley, or the roar of the Niagara at Queenston Heights. He searches deeper and deeper into the rocky crust of the globe, still finding the same types in older characters. As he climbs the rocks of Trenton or Montmorenci, he treads on the tide-ripples, the rain drops, the trails of living creatures in the ancient Silurian sea, which he interprets by the Rosetta Stone of Chelsea Beach or Charleston Harbor; and as he reverently unlocks the dark recesses which contain the traditions of the early ages, between the dead igneous rocks and the oceanic deposits which entomb the remains of life, the first objects which meet his gaze are the remains of a thin, horny shell, so like those now living in the Atlantic and Pacific waters, that the "footprint" enables him to reconstruct a Brachiopod with delicate ciliated arms and com-

plex organization, such as is figured in the beautiful works of Owen and Davidson, from dissections of the existing species.

For be it observed that shells are not things without life, as they are often taken to be by thoughtless admirers. Nor are they simply the *habitations* of "shell fish," as ordinary observers consider them. It is common to regard the snail-shell as the *house* which the creature has made and carries on its back, having a relation to the animal inhabitant analagous to that of the coccoon to the chrysalis or the nest to the bird. Even viewed in this light, shells would be most interesting objects of study; representing the different styles of architecture invented by these insignificant mechanics. Such appears to have been the way in which the great Linnæus regarded them; for he described the animals under other names than those of the shells. Indeed, he appears to have considered the houses of far more importance than their inhabitants; for, while he divided the shells into genera and species, he was content to group all the living inhabitants under five names, saying in the description of each genus "Animal a Clio," &c.* Even in his error, however, the great Father of Natural History showed his close discernment; for these five divisions correspond almost exactly to the classes afterwards prepared by Cuvier, and now generally adopted.

Let it be distinctly understood, therefore, at the outset, that shells are truly organic structures, part and parcel of the living animal, as truly as the nails of man, the plumage of birds, the armor of armadilloes and crocodiles, the scales and cartilage of fishes, or the shell of the sea urchin. They are more truly part of the living inhabitant than the skin of caterpillars or the shell of crabs, inasmuch as they are not periodically cast off, but remain, as the hardened skin of the creature, during its whole period of existence. To collect and arrange shells, therefore, bears the same relation to science as to collect and arrange stuffed birds and beasts; in either case we know only a part of the peculiarities of the animal. The mere museum-student would not know the porpoise to be a mammal; nor discriminate the manatee as being an abnormal pachyderm; nor observe the wide separation between the horse and the hoofed ruminants. So the mere conchologist would associate the Wendletrap with the top-shells, the nerites with the *Naticas*, the *Cerithiums* with the whelks, &c., not knowing that the animals are structurally as much unlike as the mammals just mentioned. It is absurd, therefore, to study shells without examination of the soft parts of the animals; while, to study the soft parts alone, without regard to the differences in the shells, would be like endeavoring to classify the cat-tribe from examination of tigers, panthers, &c., which had been previously skinned.

No one despises a collection of stuffed birds because so few of the creatures have been dissected; so we ought not to despise the study of shells because we know so little of their inhabitants. But the bird skin tells us much more about the bird than does the shell about the "shell-fish;" because the shell is the hardened skin only of a portion

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*The Linnæan Molluscs are *Sepia*, *Limax*, *Clio*, *Anomia*, and *Ascidia*. The animal of Terebratula was not then known.

of the animal, (called the mantle,) the head and foot, and other important members, not leaving any impress on their unpliant covering.

It is only of late years that enquirers have even attempted to gain information about the animals of shells. The very beauty of the shell has contributed to this result. Every sailor could collect shells, and every lady could lay them on cotton in a drawer; the animal was a nuisance, liable to rot if not carefully extracted, only to be preserved in bottles of spirit, and then presenting nothing but a shriveled or shapeless mass, fit only for the dissector's knife. Even the figures of living animals in the works of scientific voyagers are by no means infallible, it being not uncommon to find voracious proboscids figured with a vegetarian snout, or to see the shell turned the wrong way on the back of the crawler. When it is remembered that a large proportion of "shell-fish" live in deep water; that even those which surround our coasts can be but seldom examined in their natural condition; that very few will breed in confinement, and that travelers are very seldom able to dissect and examine microscopically, or even to draw correctly while on their expeditions; we must be content to wait many years before this branch of natural history is as satisfactorily established as other branches of popular science.

Let not this, however, deter any one from its pursuit. If we only collect, arrange, and study *shells*, we are doing something. We at least prepare a store of materials for future use. And every one can examine alive and report upon the shells of his own locality, whether land, fresh water, or marine. There is not a schoolboy, or a western farmer, but what may be not merely a learner of what others have done, but a gainer and teacher of fresh knowledge: while to those who can engage in scientific travel, there is open a field of original research, such as but few branches of science have left untrodden. At the present moment, we cannot agree upon the main divisions of our classification of shell-fish, for want of knowledge of the animals, habits and food of some of the commonest shells, which are annually collected by the hundred or the thousand merely for the purposes of trade.

In old days, when every one followed Linnæus, it was easy to count whether a shell had one, two, or many valves, and name it, with confidence that its place would not have to be disturbed. In the second epoch of study, after Cuvier had introduced an approximation to a natural system, all the world laid aside the artificial method, and arranged their books and shells according to the system of Lamarck. But now that we are as much in advance of Lamarck as he was of Linnæus; and every fresh animal that is examined may alter our classification; we must be content to alter and amend our books with every succeeding edition, and not allow ourselves to consider anything as fixed. The arrangement proposed in these pages may serve as an approximation to the truth, or as a starting point to begin from; neither ignoring recent discoveries, nor departing from recognized facts without better authority than hasty observations.

Another difficulty is much more serious. Most of the early naturalists, and many in our own day, have been in the habit of naming shells without describing them; or have described them so loosely that it is a matter of opinion only what they meant by their words; or have

taken no steps to make their works known in other countries. In real, and even necessary, ignorance of their labors, or in despair of understanding them, or purposely ignoring the existence of what was carelessly done, the same shells have been named over and over again, thereby burdening the memory and confusing the young student with a mass of unnecessary, meaningless, or even barbarous terms. Even this evil could be borne; for the synonymy could be made out, and henceforth all but the right name disregarded; if naturalists were agreed as to the right principles of selection. The absolute law of priority is followed by some as the most convenient. Others think that to discard names universally accepted, merely because some obscure amateur published a tract a few years earlier, or some Curator of a museum wrote his fancy names on the specimens a year in advance, or an auctioneer named his wares to effect a sale, is to strain a principle contrary to the law of use. The British Association for the advancement of Science issued a series of regulations which were generally approved, and which were republished by the American Association. But Science is a republic in which the minority refuses to be ruled by the majority; and it so happens that the newest authors have set the Scientific Associations at defiance. Those who have no access to books naturally follow the newest authorities, especially when these have deserved well of science by their discoveries. Hence we must hold our names in abeyance, and wait till better times; taking care at any rate not to add to the confusion. The limitations of the law of priority laid down by the British and American Associations appear however to be sound. A naturalist ought not to want his own name to appear, even though the first given, if the wide use of another makes it more convenient for science. Personal considerations ought always to give way to utility: because the knowledge is the end; the helpers to the acquisition of that knowledge are only means to that end. And what of honor the Christian naturalist would not claim for himself, against the uses of science, he is not bound, for the mere semblance of justice, to reserve for others. According to the laws of all civilized nations, possession of property for a given term of years confers legal right. A similar statute of limitations for scientific nomenclature would save a vast amount of time from being frittered away on merely archæological research, or worse than empty recrimination.

Those who are not deterred by the above statement of difficulties from the study of shells are recommended to possess themselves of the following works: "Woodward's Manual of the Mollusca: London, John Weale."—"Philippi's Handbuch der Conchyliologie und Malacozoologie. Halle, 1853."—"Genera of Recent Mollusca by H. & A. Adams: London, Van Voorst."—Dr. J. E. Gray's "Guide to the Systematic Distribution of Mollusca in the British Museum, London."—Chénu's "Manuel de Conchyliologie et de Paléontologie Conchyliologique: Paris." These are all cheap books. Woodward's contains by far the greatest amount of information in the smallest compass, and is well illustrated. The work of Philippi has no plates, nor has that of Gray. The Adams' figure the animals when known; but, with Gray, disregard the British Association rules, and upset the familiar Lamarckian names. Chénu's work (which, with Gray's, is still un-

finished) is for the most part a reproduction of Adams' Genera with the addition of fossils; and is chiefly valuable for its copious and accurate figures of shells illustrating the subgenera. The following pages are intended simply as an introduction to any of the above works. Books of older date are necessarily so full of errors that they should not be studied till after the student has become familiar with the present means of knowledge.

Shell-making animals have been so little known, that we have no English word to express them. They are commonly called "shell-*fish*," because most of them live in the sea. "Fish" are, properly speaking, cold-blooded vertebrates breathing by gills. It is a strange assemblage which groups with these the warm-blooded whales; the oysters and whelks; the jointed craw-fish; and the radiated star-fish. Just as we have been obliged to import the Latin word *mammal*, to include men, whales, bats and tigers, which are all warm-blooded, and suckle their young; so we must import the word *mollusk*, to include snails and slugs, oysters and clams, cuttles and tunicaries; all of which agree in having *soft bodies without jointed limbs;* the nervous system being irregularly distributed in knots, or *ganglia*, the principal of which surrounds the throat like a collar.

In general shape, they are very dissimilar from each other. Some have a large head with staring eyes; others are blind and headless. Some have many feet, others one, while whole classes have no organ of locomotion whatever. Some are so highly organized that many true fishes have to confess their inferiority: while some have special organs so little developed that it is doubtful whether they should be called degraded mollusks or superior zoophytes.

It is by no means a necessary condition of a mollusk to be shell-bearing. The lowest tribes have none; in the highest they are only occasional or rudimentary, or are altogether absent; the land and sea slugs are destitute of hard parts; and some even of the bivalves are almost entirely horny. The name "shell-fish" therefore, as applied to the whole group, will have to be given up; because myriads of species live on land and breathe air, and even the water species are not true fish; and because a large proportion of them have no shells.

Mollusks form one of the five great primary divisions of the Animal Kingdom. They rank side by side with the *Articulata*, or *Jointed Animals*, which include Spiders, Insects, Crabs, Worms, &c. The Sea-Worms, which have calcareous shells; and the Barnacles which formed part of the "multivalve shells" of Linnæus, but which are now known to be degraded crabs, used to be considered mollusks, and are still seen in collections of shells.* Strange as it may seem, these apathetic creatures have much closer relationship with spiders and butterflies. The mollusks are specially designed for eating; the artic-

* The Cirripedes were thought by early naturalists to be the fry of Barnacle Geese. Very learned descriptions are on record, illustrated by figures accurately representing the author's imaginations, showing how the barnacles grew upon trees in the water, and at last came forth from their shelly eggs as full-flown birds. The reality is scarcely less surprising than the story: for it is now known that these creatures begin life as an active little crab, with legs, head and eyes all complete, swimming about in the open sea. Instead of developing how-

ulates for locomotion. The highest mollusks are superior animals to the highest articulates; in both cases the lowest are inferior to many radiates. It is usual to rank them in parallel groups, thus:—

VERTEBRATA.

MOLLUSCA. ARTICULATA.

RADIATA.

PROTOZOA.

The VERTEBRATES include *Mammals*, *Birds*, *Reptiles*, *Amphibians*, and *Fishes*.

The RADIATES include Sea-Urchins, Jelly-fish, Coral-insects, &c.

The PROTOZOA include the simplest forms of animal life, such as sponges, animalcules, and Rhizopods or Foraminifera. These last were till lately ranked with the highest mollusks, because they make chambered shells.

The principal classes of articulates have already been pointed out: those of the mollusks are as follows.

I. CEPHALOPODS, or *Head-footed Animals*.
II. GASTEROPODS, or *Crawlers*.
III. PTEROPODS, or *Wing-footed Animals*.
IV. LAMELLIBRANCHS, or *Bivalves*.
V. PALLIOBRANCHS, or *Lamp Shells*.
VI. TUNICATES, or *Cloaked Animals*.
VII. POLYZOA, or *Molluscan Zoophytes*.

We propose to give a general description of each of these classes, which are as different from each other as are beasts, birds, and fishes; and to furnish some account of the families and more important genera. The typical mollusks are the Gasteropods, of which Snails, Limpets, Whelks, and Cowries are familiar examples. In the same way the typical Articulates are not the highly organized Spiders, but the widely diffused Insects. We shall begin, however, with the less known and aberrant Cephalopods, which hold undisputed rank at the head of all invertebrate animals.

CLASS CEPHALOPODA.

(*Cuttle-fish and their Allies.*)

Imagine a creature with two staring eyes, which he carries under his arms, and which are more complex in structure than those of many

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ever into something more perfect as do the caterpillars, tadpoles, &c., they lose not only their feet but their eyes and their very heads; adhere to rocks and sea-weed or floating timber; become almost shapeless lumps enclosed in an acorn or barnacle shell, only betraying their articulated origin by the delicate groups of feathery jointed cirri, by waving which they induce the tiny ocean currents which bring them their food. There was nothing but the resemblance of these cirri to the feathers of birds to form a groundwork for the goose story.

fishes. His nose is a long snout, or rather a pipe, which he wears under and between his eyes, as it were on his breast. He carries his mouth at the very top of his head, and could soon make one feel the bite of his powerful horny jaws, which are hooked, and work up and down like an eagle's. Although he has no legs, he is better off for arms than a monkey, having always eight or ten, sometimes a much larger number. These he elegantly arranges in a circle round his mouth; forming a crown—more dangerous than the fabled hair of serpents—round his head. His body appears only of secondary importance, and is inclosed in an oval or conical mantle, ending often in a tail like a fish, or adorned with fins, one on each side. Imagine this creature walking on his head, with his tail upwards, staring at you with both his eyes. As you watch him, he rapidly changes color, like a chameleon, by means of thousands of contractile pigment-cells all over his skin. He may change from yellow to red or brown, sometimes casting over himself a bluish tinge; the colored spots and waves appearing and disappearing with the greatest velocity. Though not a literary character, he always carries an ink-bottle, and generally a pen, along with him; and, should you chance to disturb him, he will instantly discharge a copious black stream before you, under cover of which he will dart off before you have time to follow his retreat.

The Cuttles have very acute senses. They have an approach to a brain, inclosed in a cartilaginous skull. They can hear sounds, and evidently enjoy the taste of their food. They have a large, fleshy tongue, armed with recurved prickles, like that of the lion. They either crawl on their head, tail upwards, or swim, tail foremost, by striking their arms; or squirt themselves backwards by forcing water forward, through their breathing funnels.

They are ferocious creatures, the tyrants of the lower orders, and do not scruple to attack and devour even fishes. The larger kinds are deservedly dreaded by man. Their weapons consist in their powerful arms, which are abundantly furnished with rows of cup-like suckers, each of which fastens on to its prey or its foe like a limpet to the rock. Often these are accompanied with sharp curved teeth, strong enough to be preserved even in the fossil species. "It must be a fearful thing," says Dr. Johnston, "for any living creature to come within their compass, or within their leap, for, captured by a sudden spring of several feet, made with the rapidity of lightning, entangled in the slimy, serpentine grasp of eight or ten arms, and held by the pressure of some hundreds of exhausted cups, escape is hopeless." With such strength do they clutch the object of their desire that it is often easier to tear off the limb than induce them to relax their hold.

They are the largest of all animals that are not supported by a jointed skeleton. One was seen in the equatorial Atlantic, which must have weighed two hundred weight. Another was seen in the Pacific, which must have been six feet long. As it is almost impossible to capture these great creatures alive, we remain in great ignorance about them. Montfort, one of the early conchologists, represented a "kraken octopod" in the act of scuttling a three-master; but he told his friend that, if this were "swallowed," he would in his next

edition represent him as embracing the Straits of Gibraltar, or capsizing a whole squadron of ships.

The *shell*, in the typical Cuttle-fish, is not the hardened outside skin, as in ordinary mollusks; but, if present at all, is (with one exception) an internal appendage, answering the purpose of a skeleton, but having nothing to do with protecting the nervous centres.

All the true cuttles and their allies have eight or ten arms, provided with suckers; two gills, with superadded branchial hearts; and a body shaped for an active, predatory existence. They form the

ORDER I. DIBRANCHIATA,

or *two-gilled Cuttles* of Prof. Owen. The first group are content with eight arms only; the rest have, in addition, two long arms or "tentacles," which serve to seize the prey at a greater distance.

Group I. Octopoda. (*Eight-footed Cuttles.*)

Most aberrant among these aberrant animals are the

Family Argonautidæ,

or "Paper-Sailors," so called from the delicate, white, boat-shaped shell, in which they were fabled to sail on the surface of the waters. The Argonaut was known to the ancients, one species being common in the Mediterranean. It was the *First Nautilus* of Aristotle, who, though generally so accurate, here invented or perpetuated a very pleasing fable. He described the Argonaut as sitting in its elegantly-keeled white and almost paper-like boat, holding up its two broader arms to catch the breeze, and using its other six as oars. In this position it is figured in all the older works on natural history: for either the authority of Aristotle, or the beauty of the story, caused it to be repeated from author to author, like the fable of the "Barnacle Geese." Even the naturalists of the present generation have gravely doubted whether the cuttle always found in the Paper Nautilus were the real former of the shell. A very similar shell, the Carinaria, or glassy nautilus, was known to be formed on a very different animal, a true Gasteropod. It was supposed that the greedy Octopod, having devoured the Argonaut, possessed himself of the shell, after the fashion of the hermit crabs, which may be seen crawling, tail foremost, into shell after shell, till they find one to fit them. It was reserved for a lady to set these doubts at rest. Madame Power, finding the Argonauts common in the Mediterranean, inclosed a space with net work to allow free ingress to the water, and there established her colony. She found that the Octopod was the true inhabitant of the shell, although not fastened to it by muscular attachment. She performed many experiments on her captives, the results of which have been either confirmed or corrected by succeeding naturalists. The Argonaut generally crawls on the ground with her six sucker-covered feet, carrying her shell on her back, like a snail, enveloped in the two sails, or broader arms. When she chooses to swim, she does not float above the surface of the sea; but darts through the water backwards, in the

direction of the nucleus of the shell, her sail arms still enveloping the frail bark. She generally folds her "oars" together, at arm's length, though she uses them occasionally to direct or assist her movements. What then is her propelling power? She simply *breathes herself on*, or rather *blows herself backwards*, forcing out the water from her long gill-funnel, and so is carried forward in a contrary direction. She never turns her back on her enemy; but, on the other hand, she cannot help *looking* back, wherever she is going. We say *"she;"* for strange to say, all the paper-sailors turn out to be females. For a long time the lords of the Argonaut creation eluded the anxious search of their brethren of the human species. At last they were found in the form of little stunted octopods, without any shell or sail-arms, not more than an inch long. Let tyrannical husbands see what becomes of their sex in the very highest of the invertebrate animals. The male Argonaut is not known to hold any communication with his (to him) giant mate, who lives by herself in her palatial shell. The little fellow sends one of his arms, by itself, on the courting errand; and the lady receives her spouse in the form of what was at first regarded as a parasitic leech. M. Koelliker found that what Cuvier had described as the *Hectocotylus octopodis*, was simply the contents of the left arm of the third pair on the male Argonaut, which is developed abnormally as a colored bag, and periodically gives birth to a Hectocotyle. This having been filled with spermatozoa from the body of the little Argonaut, goes forth on its independent existence, looking like an arm of an octopod ending in a thread. It lays hold on the female Argonaut with its suckers, as though it had a life of its own. It is found on her arms, clinging to her nose, or even inside the gill cavity. It clasps with such strength that it is difficult to detach it; and yet it has no mouth or other organs for maintaining life. After it has communicated the fecundating influences to the ova, it perishes. It follows that the beautiful paper nautilus is not a true shell, but simply a female appendage to deposit and mature the eggs, and at the same time protect the parent. The newly hatched Argonaut has no shell; and is said to be shaped like a worm with suckers. This beautiful group belongs only to the existing conditions of our globe. One species alone is found fossil, in the Subappenine tertiaries of Piedmont. It is now living, but not in the Mediterranean, where it is displaced by another species: it has itself migrated to the present China seas.

Family Octopodidæ.

The naked octopods resemble the male Argonaut; and some (but not all) of them have the same singular degradation of the lordly sex. They generally have small, round bodies without fins, the head and arms being the principal part of the creature. They are seldom gregarious, but crawl in the neighborhood of the shore, the small species inhabiting pools between tide marks. Here they escape detection by coloring themselves to suit the bottom, and moor themselves to crevices in the rocks awaiting their prey. They are more or less webbed between the arms, like an inverted umbrella; and progress by flap-

ping the whole at once. They can crawl at the rate of seven feet a minute; and when wishing to go quicker, they blow themselves out like a bladder, and roll over and over with great speed. They were called *polypes* by the Greeks; and some species bear a strong general resemblance to what are now called polypes, the jelly-fish, and their allies. The cuttles may be said to *represent* the radiates among the mollusks, but in their organization they are as different as birds and butterflies. The genera are *Octopus*, *Cistopus*, *Pinnoctopus*, *Eledone*, *and Cirroteuthis*. They differ in the arrangement of the suckers, and in the presence or absence of aquiferous pores in the skin and fins on the body. The *Eledone moschata* emits a strong smell of musk. The *Cirroteuthis mulleri* has its slender arms ciliated, with a web extending to their extremity. It inhabits the shores of Greenland. The

Family PHILONEXIDÆ

differ from the typical octopods in being gregarious, living in the open sea. They hide themselves by day; but towards evening come up in great shoals, to prey upon swimming mollusks and zoophytes. The genera are *Philonexis* and *Tremoctopus*.

GROUP II. DECAPODA. (*Ten-footed Cuttles.*)

These differ from the Octopods in having an additional pair of arms, much longer than the others, called tentacles. They are generally club-shaped at the end, and armed with a horny ring round the suckers, or sometimes with claws. They are within the circle of the eight arms, between the third and fourth pairs; and are (for the most part) capable of being drawn in to pouches behind the eyes. The body is long, always finned, and strengthened by an internal appendage; which is a horny pen in the squids, a "bone" in the true cuttles; a spiral, chambered shell in *Spirula;* a complex organ with a chambered shell inside in the *Belemnite* tribe. The eyes are movable in their orbits; the breathing funnel is generally provided with a valve; and the mantle is supported by internal fleshy bands.

Family CRANCHIADÆ.

The *Cranchia* is a pot-bellied little creature, with very small head and eyes. These are covered by the skin; the mantle is supported by two internal fleshy bands; and the breathing-pipe has a valve.

Family LOLIGOPSIDÆ. (*Calamaries.*)

In *Loligopsis*, which is a very long animal with a small head, the eyes are large and beautiful, and the breathing-pipe is without valve.

Family CHIROTEUTHIDÆ. (*Hand-Calimaries.*)

The body of the Hand-calamary, (*Chiroteuthis*,) seems only like a fulcrum, from which to move its powerful head organs. Though only two inches long, the arms are eight inches, and the tentacles extend

three feet. It must be remembered that these are not mere feelers, like the antennæ of insects, but strong muscular threads beaded with suckers, and armed with four rows of pedunculated claws on the expanded ends. How easily these will encircle any unhappy creature floating at a distance, and carry it to the mouth, to be torn up by the horny bills, is at once evident. How so small a body can work the muscles at such a tremendous leverage, without any support but a loose horny pen, is indeed a marvel.

The *Veiled-calamaries*, (*Histioteuthis*,) have six of their arms webbed together, leaving the other arms and tentacles loose. It resembles half an expanded umbrella. One of the species "rivals in color the brilliancy of the butterflies of tropical suns. The large membrane which unites its arms is of a rich purple, and the suckers are sapphire, the under surface being studded with blue and yellow spots on a reddish ground, sprinkled with purple spots."

Family ONYCHOTEUTHIDÆ. (*Sea-Arrows.*)

These creatures have the mantle supported by three internal cartilages. The eyes are exposed, and furnished with a slit above. The breathing-pipe has a valve, as in *Cranchia*. They are very numerous, and have been divided into the following genera: *Enoploteuthis* (Armed-calamary), *Ancistrocheirus*, *Abralia*, *Verania*, *Acanthoteuthis*, (Spiny-calamary); *Onychoteuthis* (Hooked-calamary); *Ancistroteuthis*, *Onychia; Ommastrephes* (Sea-Arrows, or Flying-squids); and *Thysanoteuthis* (Fringed-calamary).

Among the active cephalopods, perhaps the most vigorous swimmers are the *Armed calamaries*. They are the dread of the shell divers of the Pacific Islands; for the arms have, beside the suckers, double rows of horny hooks concealed by retractile webs. A cat's paw is quite sufficiently disagreeable, with her five claws; but for a bather to feel his naked body embraced with eight snake-like arms, with cat's-paw weapons on the whole length, and leech-like suckers in addition, to say nothing of the long tentacles still more powerfully armed,* and directed by two great staring eyes, much more serviceable than a man's in the water, the possessor of which can instantly hide himself by a discharge of ink, is not pleasant even from a creature the size of a cat: but when it is remembered that some of them are six feet across, and that they do not kill quickly like the shark, but tear their prey piecemeal, we feel thankful to live in safer latitudes. In the *Hooked calamaries*, besides the hook-armed cups, there is a group of ordinary suckers, at the beginning of the expanded part of the tentacles. When these touch each other, they resemble the hinge of a pair of pliers, and the unfortunate beast hooked in between the flaps is drawn by the united strength of both arms to be torn to death at the top of the cuttle's head. It is a merciful provision that his great eyes, so necessary for him in locomotion and attack, are spared the sight of the tortures he inflicts upon his prey. The hooks

*The tentacle suckers of the calamary suggested the obstetric forceps of Prof. Simpson.

found fossil in the German Jurassic strata, with the traces of the cuttle itself, prove that the *Spiny calamaries* were equally the tyrants of the ancient seas. The *Sea-arrows* live in large groups in the open sea. They are themselves the prey of whales and birds. In order to avoid the attacks of their pursuers, they dart out of the water like the flying fish, often to such a height that they fall down on the decks of vessels. The eyes of these creatures have a deep lachrymal groove at the upper edge, and the ears are furnished with a longitudinal crest.

Family TEUTHIDÆ. (*Squids.*)

In the Squids the eyes are without lids, and covered with the skin, as in *Cranchia;* but the mantle is strengthened with internal cartilages, as in the Sea-arrows. The genera are *Gonatus*, *Loligo*, *Teuthis*, *Sepioteuthis*, *Rossia*, *Sepiola*, and *Fidenas;* with the fossil remains of *Leptoteuthis*, *Teudopsis*, *Beloteuthis*, and *Geoteuthis*.

The *Squids* form an important element in the North Atlantic fisheries. The common *Loligo* is the favorite food of the Cod, and is therefore itself fished for bait. One half of all the cod taken on the banks of Newfoundland are said to be caught by it. "When the vast shoals of this mollusk approach the coast, hundreds of vessels are ready to capture them, forming an extensive cuttle fishery, engaging five hundred sail of French, English, and American ships. During violent gales of wind, hundreds of tons of them are often thrown up together in beds on the flat beaches, the decay of which spreads an intolerable effluvium around." They must themselves be consumed in enormous numbers; for it has been estimated that a single squid will lay in one season forty thousand eggs. The pens of the squid tribe are loose supports in a pouch along the back. In old individuals, sometimes two or three are found laid together. They are analogous to the "bones" or steel plates in ladies' stays—an instrument which ought not to be needed by a vertebrated animal.

The *Sepiolas* are pretty little creatures, with round purse-like bodies, and a wing-like fin on each side. They live near shore, and may often be seen darting about in rocky pools. They are considered a delicacy in the South of France, where they are called *supieta*.

The squids first make their appearance in the world's history during the epoch of the Lias and Oxford Clay. The octopods may, indeed, have existed, but their bodies have no hard parts that would be likely to leave traces on the ancient rocks. Of the squids, not only the horny pens and claws have been preserved, but even the muscular mantle, the bottoms of the arms, and the ink bag filled with sepia which an artist might envy. They must have died a very peaceful death, as they always spill their ink under the slightest provocation. Some of the ink bags of the Lias are nearly a foot long, with a brilliant pearly coat. They probably formed part of the food of the formidable Ichthyosaurians of that epoch.

Family SEPIADÆ. (*True Cuttles.*)

The Cuttle-fish proper are furnished with a "bone," which consists, on the back, of a hard, shelly dish, covered with membrane and end-

ing in a knob, and built up within with layer upon layer of very delicate wafer-like shelly plates, supported by numerous vertical pillars.* It is, therefore, very light and porous, at the same time that the shape and texture of the back give it great power of support. The cuttles are the least elegant of the tribe, having a large, flatish body, finned along the whole of each side. The knob, doubtless, protects the creature's tail from blows as it swims backward near the shore. The Chinese cuttle bones are sometimes eighteen inches long.

Most persons have seen the delicate *Spirula*, transparent and white, shaped like a ram's horn divided across by pearly chambers. A mere conchologist would never suspect any close resemblance between this and the cuttle-bone. They are, however, so closely connected by intermediate fossil forms, that, without a knowledge of their animal, it is difficult to say to which family these belong. No less different at first sight are the "thunderbolt stones," so common in the Jurassic and cretaceous rocks of Europe. In the world's history, they begin and end with these rocks. They were suddenly poured, in incalculable abundance, on our planet; and as suddenly they became entirely extinct. The

Family BELEMNITIDÆ

consisted of cuttles whose body was strengthened by a long pen, joining on, at the tail end, to a conical chambered shell, the air-cells of which were connected by a siphuncle at the side. This conical shell (formerly called the *alveolus* of the belemnite, and now known as the *phragmocone*,) was invested, at the tail end, with a longer cone or guard. This is fibrous, consisting of long prismatic cells, like the shell of the recent pinnas or the great cretaceous Inocerami, with which it entirely agrees in specific gravity. This guard is the "thunderbolt stone" of the common people, and is generally preserved entire, while the chambers are often destroyed, and the pen has almost always perished. The most perfect specimens were found in the Oxford Clay, and are preserved in the British museum and in the cabinet of Dr. Mantell. Fragments of the chambered part, in the Lias and Oolite, are very like the then-extinct orthoceratites, though the animal is widely different. The *last chamber* alone sometimes measures six inches by two and a half; so that its cuttle must have been nearly three feet long. A fortunate breakage, in a specimen in the British museum, displays an ink-bag near the siphuncle, at once showing that it was an active swimmer, like the cuttles. The length of the guard is very variable in the same species, sometimes attaining to two feet. The septa frequently perish, leaving the chambers, which have been filled with calcareous spar, lying loosely on each other like a pile of watch glasses.

The Belemnites were gregarious, and probably lived in a moderate depth of water. The classical writers before Pliny gravely supposed that they were the hardened contents of the bladder of the lynx;

*This substance, when reduced to powder, is called pounce. Among other uses, when rubbed on paper after "scratching out," it prevents the ink from running.

whence they bore the name lyncurium. The writers of the middle ages called them "ghosts' candles," "devil's fingers," "night mare's arrows," &c. The more learned supposed they might be petrified amber, fossil dates, stalactites, or spines of sea urchins. It was not till the beginning of the present century that their true nature was understood. The grooved *Belemnitella mucronata*, which is characteristic of the chalk and Upper Green Sand, is found on both sides of the Atlantic.

Although the Belemnite itself has not been found preserved, its next door neighbor, the *Belemnoteuthis*, has been discovered at Chippenham, (England,) with its shell, muscular mantle, fins, ink-bag, funnel, eyes, arms, and horny hooks, all complete, as if thrown by the tide upon our present shore. The hooks are formidable weapons, from twenty to forty pairs appearing on each arm. In this creature the guard is very thin. In *Conotenthis*, an active swimmer of the Neocomian age, we have a very long pen terminating in a phragmocone shaped like a paper funnel; forming an exact transition from the Squids to the Belemnites.

Family Spirulidæ.

The shells of *Spirula* are as common in tropical seas now, as were the *Belemnites* in those of the middle ages. Their resemblance to the pearly nautilus and other allied chambered shells, and especially to the fossil *Gyroceras*, or *Crioceras*, is very striking. Here is a loosely-coiled spiral shell, regularly divided by concave septa, like the Nautilus, each one pierced by a tubular siphuncle. But the resemblance is superficial only. The last chamber of the nautilus tribe is always large, and *contains* the animal, which is fastened to it by powerful muscles. Whereas the last septm of the *Spirula* is almost close to the margin, indicating that it is an internal shell, enveloped in the mantle of the cuttle-fish like the bone of the Sepia. Although the shell always forms part of the fancy collections from the Bahama Islands, and it is scattered by thousands on the shores of New Zealand, a perfect specimen of the animal has not yet been seen. It is, however, formed on the usual decapodous type; only the fins and arm-cups are very small. The ink-bag lies against the last chamber of the shell. Beautiful as the *Spirula* is, it is still more so when the outer coat on one side has been removed, by allowing it to float on dilute muriatic acid, so as to display the siphuncled septa.

Among recent shells, the *Spirula* stands by itself; but it is connected with the Belemnites and Squids by fossil forms. In *Spirulirostra*, from the Miocene of Turin, we have a very loose spiral siphunculated shell immersed in a kind of cuttle bone of irregular shape. In *Belloptera*, a fossil of the Nummulite age, the chambered part is nearly straight, and surrounded by a "bone" formed by two inverted cones with winged processes between. In *Belemnosis*, a unique fossil of the London Clay, the bone is not winged. In *Helicerus*, a fossil described by Professor Dana from the slate rocks of Cape Horn, there is a guard, as in the Belemnites, inclosing a chambered shell somewhat spiral at the nucleus.

ORDER II. TETRABRANCHIATA,

or *four-gilled* cephalopods, of Professor Owen. It might be thought a matter of little importance whether a cephalopod had one or two pairs of gills; but it happens that this difference is coördinate with others that run through the whole form and structure of the animals. The two-gilled cuttles, we have seen, are adapted for an active and predacious life. As they could not dart after their prey carrying a heavy shell, they are naked, but furnished with powerful arms and ink-bag for their protection. The four-gilled tribes, on the other hand, are destined for a quieter life, crawling on the ground like common Gasteropods. Instead of eight or ten arms with suckers and hooks, they have a multitude of small retractile feelers, something like the Sea Anemone. On these they can creep, and draw their prey to their mouths; but they are not able to pursue it in the open sea. Instead of a strong breathing tube with a valve, answering the purpose of a forcing pump and propeller, they have only an open gutter made by a fold in the mantle, like the siphons of the Gasteropods. The eyes, which in the cuttles have optic ganglia much larger than the central brain, (*Alcock*,) are here less conspicuous, and mounted on peduncles. The head and tentacles, instead of being the principal part of the creature, to which the body might appear subordinate, are here scarcely separated from it, and retractile within the general mass. They are always furnished with a chambered shell, the last cavity of which contains the animal. When disturbed, instead of squirting ink and darting off, it shrivels up into its cavity and takes its chance. If it sees a delicate crab at a distance, instead of pouncing on it, it must crawl, not, indeed, on "all fours," but on "all dozens;" or wait until the creature comes within seizing distance, when it will be entangled in the arms and be broken up by the jaws or gizzard.

Only one animal formed after this type is now known to be living on the earth; the *pearly* or true *Nautilus*, whose many-chambered shell has been an object of admiring speculation from early times. This is the last straggler belonging to a race which performed important functions in the early ages of our globe. The *Nautili* themselves are among the few genera which have existed at every period of the world's history. Our knowledge begins with one species from the upper silurian rocks of Bohemia. It has not culminated at any particular period; not more than seven species appearing in any formation; but it has never been without its representatives, and two or three species are now crawling on the sea bottoms in the East Indian archipelago. Before them, however, lived the great *Orthoceratites* of the palæozoic seas; and as they died out, the great family of the *Ammonites* developed themselves, and held possession of the seas till the close of the cretaceous period, when they suddenly disappeared, leaving not even a distant relation to grace the tertiary formations. Coördinate with the prevalence of four-gilled Cephalopods, we find a general absence of the predacious Gasteropods which are now so numerous and highly developed. We may suppose, therefore, that they played the same part in the economy of nature; and that the *Orthoceratites* and

Ammonites did the work of destruction in ancient times, which is now performed by murices, strombs, whelks, and their allies.

The chambered shell is always pearly within, but with an external porcellanous layer. The Chinese are fond of leaving patterns carved on the Nautilus while the body of the shell is uncoated, to show the nacre. In fossils sometimes the outer coat has perished, sometimes the inner, and sometimes both. The chambers are always connected by a siphuncle, through which the animal maintains a connection with the deserted chambers. These are lined with a very thin living membrane in the *Nautilus*; in the *Orthoceratites* they show the marks of blood-vessels, &c., which prove that they played some unknown part in the economy of the animals. That these air-chambers serve as a float, to balance the weight of the shell and enable the creature to swim if needful, cannot be doubted; but the stories of their filling the cells with air or water at pleasure, and so sailing at the top or descending to the bottom, appear to be fables, like the classical legends of the Argonaut. The living Nautilus only comes to the surface occasionally, when the sea bottom has been agitated by storms; and it is believed that the fossil species inhabited depths not greater than thirty fathoms. The chambers are filled with nitrogen gas, without oxygen or carbonic acid. The animal is attached to the shell by powerful adductor muscles. As these grow onwards, the animal gradually deserts the last chamber; and, at periodic periods of rest, a fresh septum is formed.*

If a diving bell had explored what is now called New York and

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*The following lines have the rare merit of not losing truth at the same time that they are highly poetical. They are copied from the "Atlantic Monthly." Let the reader take in his hand a pearly Nautilus cut through the middle, and say—

This is the Ship of Pearl, which, poets feign,
Sails the unshadowed main;
The venturous bark, that flings
On the sweet summer wind its purpled wings,
In gulfs enchanted, where the siren sings,
And coral reefs lie bare;
Where cold sea-maids rise, to sun their streaming hair.

Its web of living gauze no more unfurl;
Wrecked is the ship of pearl!
And every chambered cell,
Where its dim, dreaming life was wont to dwell,
As the frail tenant shaped his growing shell,
Before thee lies revealed;
Its irised ceiling rent, its sunless crypt unsealed!

Year after year behold the silent toil
That spread his lustrous coil;
Still, as the spiral grew,
He left his past year's dwelling for the new;
Stole, with soft step, its shining archway through;
Built up its idle door,
Stretched in his last-found home, and knew the old no more.

Canada when they lay at the bottom of the palæozoic seas, it would have encountered multitudes of long pointed shelly cones, floating upright in the water, some of them adorned with beautiful colors and sculpture, and slowly moving among the corals, sea-weeds, and stone-lilies which then adorned the gardens of the great deep. They belonged to the

Family ORTHOCERATIDÆ,

or *Straight-horns*. Some of them carried on their backs the largest shells that ever lived. A specimen belonging to Col. Jewett, of Albany, now measures twelve feet, and when perfect must have been fifteen feet in length. And yet, from the buoyancy of its contained air, the comparatively feeble cephalopod could maintain its enormous leverage, and crawl on its slender tentacles. The aperture of the *Orthoceratites* is generally contracted, and the head was perhaps always exposed. The siphuncle is very large, and in some of the genera very curiously formed, indicating much more vitality than in the corresponding part of the Spiral Nautilus. This was necessary in order to maintain a living connection at such a distance from the body. All the orthoceratites have simple, concave chambers, with a central opening. They disappear at the beginning of the secondary rocks, leaving their work to be performed by the huge *Ammonites* of the Lias. In *Gonioceras*, the shell is flattened, and the septa waved. In *Actinoceras, Hormoceras* and *Huronia*, the siphuncular processes are enormously developed around the central tube, according to different patterns. In *Thoracoceras* and *Cameroceras*, the siphuncle is marginal, and generally small. The strange fossils called *Endoceras* by Prof. Hall have very long slender shells, with a large cylindrical siphuncle, somewhat lateral. This is thickened internally by separate layers of shell, or funnel tubes one inside the other, called "embryo tubes" by the author, contrary however to all analogy. Their use may have been to give increased strength in consequence of the great elongation of the shell. Some of the species appear to have been constituted from the accident of a young shell being lodged in the siphuncular cavity: others from the monstrous formation of a second siphuncle.

Thanks for the heavenly message brought by thee,
Child of the wandering sea,
Cast from her lap forlorn!
From thy dead lips a clearer note is borne
Than ever Triton blew from wreathed horn!
While on mine ear it rings,
Through the deep caves of thought I hear a voice that sings:—

"Build thee more stately mansions, O my soul,
As the swift seasons roll!
Leave thy low-vaulted past!
Let each new temple, nobler than the last,
Shut thee from heaven, with a dome *more* vast;
Till thou at length art free,
Leaving thine outgrown shell, by life's unresting sea!

The *Phragmoceras* and *Oncoceras* form a sub-family, in which the shell is pear-shaped and contracted at each end.

The bent forms constitute another sub-family, and were perhaps more nearly related to the Nautilus. *Cyrtoceras* is slightly curved, and shaped like a gigantic Cæcum.* *Gyroceras* developes a shape like Spirula; and *Ascoceras* displays a shell bent upon itself, like *Ptychoceras* among the Ammonites.

Family NAUTILIDÆ.

In the living Nautilus, the only interpreter of the great group of Tentacular Cephalopods (as D'Orbigny calls the order) the horny beaks are surrounded with shelly matter, giving them great crushing power over the shells of crustaceans. Similar beaks have been found fossil in various strata, associated with Nautili. In the Muschelkalk of Bavaria, where there is only one species of Nautilus, the upper beak has been described as *Rhyncolites hirundo*, and the under beak as "*Conchorhyncus avirostris.*" D'Orbigny has turned these mandibles into cuttle bones, under the names of *Rhyncoteuthis* and *Palæoteuthis;* one out of the many instances in which a knowledge of comparative anatomy is shown to be essential to the study of organic remains. Round the mandibles is a circular fleshy lip; round which again are about four dozen labial tentacles, answering to the "buccal membrane" of the cuttles, and serving to bring the prey to the mouth. Beyond these are a double series of tentacles, thirty-six in number, answering to the ordinary arms of the cuttles. When the creature is expanded for crawling or seizing prey, these would project somewhat in the form of a figure 8, the mouth being between the two groups of tentacles. When the creature retires into its shell, it protects the opening with a hood, which answers to the back pair of arms, united together and developed for that purpose, as are one pair in the female Argonaut to envelop the shell. The tentacles shut up in bunches into sheaths, which correspond to the eight common arms of the cuttles. Besides these there are four tentacles, one on each side of each eye: these appear to be feelers as in the Gasteropods. It is easy to see how much more highly organized and active is the *paper*, than its distant relative the *Pearly* Nautilus. In each case, all the animals examined have been females. It has been supposed that the shell-forms with a wide opening at the axis of the spire, belong to the males, which, as in the other Cephalopods, are few in number. Similar differences are found in almost all the Ammonites.

The Fossil Nautili present several sections, differing more or less in type from the recent species. In *Cryptoceras*, the siphuncle is nearly external, as in the Ammonites, which it resembles in external form. In *Temnocheilus*, the shell is carinated. In *Discites* all the whirls are exposed and flattened. These sections are from the palæozoic rocks. The "*Ellipsolithes*" were simply Nautili and Ammonites which had been accidentally compressed into an oval shape.

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* The *Corniculina* figured by Munster as a chambered shell, is probably only a badly observed Cæcid.

In the *Lituites* of the ancient seas, we have a Nautilus, which, on coming to maturity, produced its tube in a straight line. The *Hortolus* resembles it, but with the whirls separate as in *Spirula*. In *Trochoceras*, we find the spire more or less elevated, as in snails.

The sub-family CLYMENIDÆ consists of forms in which the chambers are more or less waved or indented, forming a slight approach to the Ammonites. They are all palæozoic forms, except *Aturia*, which makes its appearance unexpectedly in the London Clay. This has a very large internal siphon, like a number of funnels interwrapping each other, and reminding us somewhat of *Endoceras* among the Orthoceratites.

Family AMMONITIDÆ. (*Ram's-Horn Shells.*)

This group, so abundant in the middle ages both in species and in individuals, suddenly passed out of existence at the close of the cretaceous age. The body of the Ammonites was long in proportion: the opening of the shell was guarded by curiously-shaped processes, and closed by a double operculum. In the beautiful flat Ammonites of the Oxford Clay, the shell makes two long forceps-shaped beaks, one on each side of the mouth. In another species, these beaks arch over the mouth and meet in the middle, leaving one hole for the head to crawl out at, and the other for the opercle-bearing arms. In other species, the aperture is almost closed up, as in many snails.

In the keeled species, the operculum was of one horny piece, as in Gasteropods: but in the round-backed groups, it was shelly, and divided into two plates. Forty-five kinds have been described, one being from the palæozoic rocks. They were called *Trigonellites* by the old writers, and doctors still disagree as to their nature. D'Orbigny thought them cirripedes: Meyer, bivalve shells: Sowerby, fish palates: Deshayes, gizzards of Ammonites: Coquand (followed by Chénu) cuttle bones. They have however sometimes been found in situ, exactly answering to the hood of the Nautilus.

But the most remarkable character of the Ammonites is the *sutures*, or edges of the chambers. When an Ammonite is sliced down the middle, the septa simply appear waved as in *Clymene*. But when the outer shell is removed, and the cast of the edges is displayed, we find a beautiful leafy structure, often of very intricate pattern, but constant in each species. The siphuncle is always external. The outside is almost always very beautifully ornamented, with ribs, knobs, spines, or delicate striæ. The under layer is always pearly, as in Nautilus; and beautiful objects they must indeed have been, when painted with various colors and patterns, to those who could have seen them with oolitic or cretaceous eyes. Some of them are of enormous size, measuring occasionally two feet in diameter. These are found in the Lias, and in the neighborhood of Bristol (England) may often be seen built into the walls by the road side. More than five hundred and thirty species are already known. They are rare in America, but very common in Europe. Species, similar to those of the English oolite, have been found in the high passes of the Himalaya, more than 16,000 feet above the level of the sea.

The most ancient of the tribe are the *Goniatites*, of the Upper Silu-

rian and Carboniferous seas. In these, the sutures are not foliated, but simply lobed, often at sharp angles. In the *ceratites* of the Muschelkalk series, the alternate lobes are denticulated. The *Goniatite*, when the spire is unrolled into a straight cone, like the Orthoceratites, becomes a *Bactrite;* and the *Ceratite*, similarly unrolled, becomes a *Baculina*.

The true *Ammonites*, with minutely lobed septa, present all varieties of shape; from the compressed forms, with the whirls scarcely touching, to the involute species, with round backs, narrow chambers, and very small umbilicus. They have been variously divided into groups by different authors; but they pass into each other by very slight distinctions. Often a shell, which in its earlier stages would belong to one group, develops into a different one as it approaches maturity.

The Ammonites present various aberrant forms, some corresponding to those already mentioned among the Nautili, some peculiar to themselves. In *Crioceras* the whirls are separate, as in *Spirula*. In *Scaphites*, the shell begins like an Ammonite, the mouth is next produced at a tangent, and then bent back upon itself. It would be curious to know how such creatures got their living. *Ancyloceras* combines the characters of the two last genera, beginning as *Spirula*, and ending as *Scaphites*. *Anisoceras* has the same form, but drawn out of the plane into an irregular spiral, like *Vermetus*. *Toxoceras* presents a simple cycloidal curve. In *Hamites*, the shell begins quite straight, then bends and returns again parallel to itself, and so on, like a *Spirula* drawn out and flattened on its two sides. In the section *Hamulina*, the shell only makes one bend, the two parallel limbs having different sculptures, and the body-chamber occupying one limb and the elbow. The *Ptychoceras* is like a *Hamulina*, with the two limbs joined together; still with different sculptures, so that fragments might easily be described as distinct species. In *Baculites*, the shell is quite straight, like a walking stick. It is so common in the Normandy chalk as to give it the name of Baculite Limestone.

In the *Terrilite* group, we have an approach to the ordinary shape of the univalve spiral shells. They are mostly reversed, and are supposed by Woodward to have had one pair of gills atrophied. In *Heteroceras*, after beginning as a *Turrilite*, the shell becomes separate, as in the adolescent *Vermetus*, and makes an irregular spire eveloping, but not touching, the spire. The *Helicoceras* is as it were a *Turrilite*, with all the whirls drawn out into a corkscrew.

We have now enumerated the principal known forms of Cephalopods, both extinct and living. While they are the most highly organized of invertebrates, they cannot be considered as *typical* mollusks; that is, they do not represent the idea of molluscan life, as do the ordinary Gasteropods which we have next to consider. Now those classes which go off from the standard idea are generally pretty well defined; while those in which the normal idea culminates are more variable in structure. We have seen that the cephalopods are all formed on two well-marked but distinct types; and however much the shell of the *Baculite* may differ from the *Nautilus*, or the Argonaut's egg-case from the cuttle-bone, a beginner even could never doubt con-

cerning the class of a cephalopod if he saw it alive: for though star-fish and polypes, as well as Bryozoa, have a central mouth surrounded by arms or feelers, the great eyes and funnel, as well as the soft but muscular body, would at once assign its position. It is not so with the Gasteropods. To say nothing of the different shapes of the shell, as e. g. in *Chiton*, *Dentalium*, *Patella*, *Trochus*, *Vermetus*, *Cyprœa*, *Murex*, and *Carinaria*, the shapes of the animals are so very unlike that even now naturalists are not agreed as to the limits of the class; still less on the arrangement of its fundamental divisions; least of all, on the position of particular families and genera. This should by no means discourage the student; but on the contrary fill him with zeal to prosecute a study in which so many unworked materials are within his own reach; and in which, therefore, instead of merely following at a remote distance in the steps of the learned, he may, without neglecting the main duties of his life, add materially to the stores of human knowledge, and even throw important light on the dark places of our planet's ancient history.

CLASS GASTEROPODA;

that is, *belly-footed* animals, or *crawlers:* comprising *snails*, *periwinkles*, *whelks*, *limpets*, and "univalve shell-fish" generally.

These creatures form three-fourths of the whole number of mollusks. They inhabit sea-shores, and the sea-bottoms, down to the lowest depths of ordinary animal life: they are found swimming in the open seas, or accompanying the floating gulf weed: or they live in fresh waters, crawling on stones or aquatic plants. Lastly, they are found on dry land, in all kinds of situations where lime exists; either in damp and marshy places, or in rocky deserts; either burrowing in earth or crevices, or creeping on the vegetation of forests, herbage, or lichen-covered stones. One cannot live anywhere, therefore, where crawling mollusks are not within our reach. The following classification may aid us in understanding these many-shaped creatures:

Class.	*Sub-classes.*	*Orders.*	*Examples.*
GASTEROPODS.	PROSOBRANCHS.	PECTINIBRANCHS	Whelks, Cones, Strombs, Cowries, Periwinkles.
		SCUTIBRANCHS	Limpets, Chitons, Sea-ears, Topshells.
		CIRROBRANCHS	Tooth Shells.
	PULMONATES		Snails.
	OPISTHOBRANCHS.	TECTIBRANCHS	Bullas, Sea Hares, Umbrellas.
		NUDIBRANCHS	Doris, Eolis, &c.
	NUCLEOBRANCHS		Carinaria, Janthina.

In the PROSOBRANCHS, the breathing cavity is at the back of the head, *in advance of the heart*. There is always a distinct shell, which generally covers the animal. They form two principal groups, (1) the *Pectinibranchs*, in which the gill is comb-shaped, and the animal unisexual: and (2) the *Scutibranchs*, in which the gills are in plates, like the bivalves, and the animal has the sexes united. The *Cirrobranchs* are a small and very aberrant group.

In the OPISTHOBRANCHS, the gills are *behind the heart*, and very variable in position and structure. There is no shell, except in a few families of the *Tectibranchs*, in which the gills are covered by the

mantle. In the *Nudibranchs*, they form ornamental excrescences, more or less diffused over the body. The sexes are always united.

In all the water shell-fish, the animal after birth undergoes a metamorphosis, as in the insect tribe, before it assumes its normal condition; but in the intermediate tribe of SNAILS, the creature is born into its proper shape. The sexes are united, as in the Opisthobranchs.

The NUCLEOBRANCHS have the gills in a tuft at the lower part of the back, sometimes protected by a shell. They do not crawl like true Gasteropods, but are an aberrant group passing over to the Pteropods. They swim in the open sea; and while they devour the jelly-fish, are themselves the prey of true fishes and cuttles.

ORDER PECTINIBRANCHIATA. (*Comb-gilled Crawlers.*)

All these creatures have a spiral body, guarded by a shell. When they walk about, the liver and other viscera remain in the upper portion of the shell: but a large fleshy foot is protruded, on which the animal crawls; as also the head, with a distinct neck. On the head are a pair of tentacles, (commonly called "horns," from their similarity of position with the cow's horns,) which are extremely delicate organs of sense. The eyes are on these, or at their base; or, sometimes, on little eye-stalks near. In front is the snout, which is either short, as in the periwinkles, or produced into a long trunk, as in the carrion-feeding Strombs. Sometimes it appears very short and innocent; but really it has swallowed, and can at any moment dart out, an enormous proboscis, armed with powerful rows of teeth. The bottom of the shell is in reality its front; for there the animal breathes; there being either a pipe or a hole to let the water-current in to the gills. The alimentary canal is doubled back over itself, terminating near the gills, so as to be able to act, when the creature is at rest in his shell. There are seldom any differences observable in the shells of the two sexes. The intromittent organ is near the head, and generally very long; varying considerably in shape in the different genera. At the end of the foot is a horny *operculum* or toe nail; which is drawn in last of all into the shell, and serves to close its aperture, like a trap-door.

Remembering that the shell is part and parcel of the living animal—a secretion from its muscular skin or *mantle*—of truly organized structure, though not endowed with feeling; we shall naturally expect to find differences in the shell corresponding with those in the sentient inhabitant. This is generally, but not always, the case. Lamarck thought that all creatures with a round-mouthed shell were herbivorous, and all those with a notched mouth carnivorous; but now it is known that some round-mouthed groups are very fierce, as *Natica* and *Scalaria*, while some that were thought predacious, as *Cerithium*, are vegetarians. In *Melania* and *Io*, *Bulimus* and *Achatina*, we have both forms of shell in one family. So Clark imagined that all creatures with many-whirled opercula were hermaphrodites; all with few whirls unisexual. But the hermaphrodite Nerites have few whirls; while *Modulus* among the Periwinkles, and *Cerithidea* among the Cerites, differ from the other members of their unisexual families in having

many whirls. The study of mollusks is calculated to warn any student against hasty generalizations. He is continually finding characters important in one family, which prove of little moment in another: marks which he has long rightfully considered coördinate with special distinctions, appearing again in quite different connections, as well as essential differences of animal appearing, where there was nothing in the shell to lead to their suspicion. An artificial classification, therefore, however convenient as an *index* to characters and species, does not convey that knowledge of the whole relationships of the animal, which we ought at least to seek to express. It is to be regretted that some of the most learned of modern writers have gone on this artificial plan; and, from a determination to be guided by certain special characters as fundamental, have grouped together very unlike creatures, and separated others with natural affinities, to the great perplexing of beginners. Thus, in the arrangement followed at the British Museum, the Gasteropods and bivalves are grouped together, simply because they have a foot; and the Lamp-shells, Pteropods, and Cephalopods together, because they have none: the noble Cuttles being degraded to the lowest rank among mollusks; and two closely allied classes of bivalve shells, as well as the nearly related Gasteropods and Pteropods being separated in the primary division, simply because they have or have not a *foot*—a character which varies to the greatest extent within each separate class; for many of the Heteropods among the crawlers have not so much of foot as the cuttles, and the oysters among the bivalves have none at all. The same grouping, according to individual characters, prevails throughout the subordinate divisions. But there is a difference between a *classification* and an *index*. The Linnæan grouping of plants is an admirable *index;* by consulting which an unknown flower may be at once put into its proper place; but it tells very little, and that little often erroneously, of the true relationships of plants. The "Natural System" is much harder to learn, and requires constant alterations; but, so far as it is ascertained, it is a compendium of the existing state of science. So the British Museum method is an admirable index; for a student, having a fresh animal under examination, can at once arrange it under its appropriate "Suborder, Tribe, A, a, *, †," &c.; but whether he is showing, or upsetting its true relationships by this process, is yet to be seen. It was thought in the days of Lamarck that animals, if fully known, might be arranged in a straight line, gradually ascending from the monad to man. Every progress in our discoveries impinges upon this idea, and shows that we cannot even arrange by radiations or circles in one plane. We have to branch off into space, like the suns in the universe: the attractions of each, with its attendants in orbits of different planes, being to every other. To express this in a superficial way on paper must needs only give us partial impressions, which nothing but patient study can develop into even an approximation to the truth.

The comb-gilled crawlers very naturally divide themselves into those with a long retractile proboscis, which can be drawn into the mouth or extended at pleasure; and those with an external muzzle, more or less produced into a snout. The first group are all preda-

cious, rasping the flesh or sucking the juices of other mollusks, crustaceans, or zoophytes. The second group are variously organized, according as they scour the shores for carrion, browse on the sea weed, or are satisfied, like the bivalves, with the organic matter that the sea wafts to their mouths. In each group we find creatures of equally high organization, as *e. g.*, the whelks and strombs; in each, some very low, as *Magilus* and *Vermetus*. As a general rule, the operculum in the predacious group is in concentric layers; in the vegetable-feeders, more or less spiral in its growth.

GROUP PROBOSCIDIFERA. (*Crawlers, with Retractile Proboscis.*)

All these creatures are able to swallow their snouts and their tongues. They have sharp tentacles, with the eyes generally placed on knobs, part way up their sides. They have thin necks; and, when not hungry, appear very innocent, as well as graceful creatures, the dangerous organs being quite concealed. Their foot is large, flat, and spreading, more separate from the body than in the snails. But when their hungry or ferocious instincts are aroused, they dart out a long trunk, sometimes even longer than their shell, at the end of which are various drilling teeth, so arranged that they can bore a hole, even in the strongest shells, and suck out the unfortunate inhabitant. Every one must have observed these accurately turned holes, especially near the hinge of bivalve shells. Besides this drill-bearing trunk, they have a long horny tongue, or "lingual ribbon," armed with hundreds of teeth, arranged in various patterns, which differ in the various families. These tongues, when at rest, lie coiled up in a cavity near the stomach. They do not make such quick work with their prey as do the cuttles. Fancy the condition of an unfortunate clam or mussel, resting peaceably in his bivalve shield, as he hears a grating noise, outside his liver, going on hour after hour, he knows not why. At last he feels the drill, and then the horny tongue, entering his vitals, and he is sucked out of existence without possibility of defense!

The shell of the Trunk-bearers may almost always be known by a notch or canal at the base; the object of which is to protect, or at any rate allow the egress of the breathing pipe, which, as in the Nautilus, is an open gutter formed by a lengthening and folding of the mantle. In most of the tribe the trunk is drawn in base foremost; but in the aberrant group of Cowries, Dr. Stimpson has observed that the tip is first swallowed. In another group, of which the Cones are the type, there is said to be no separate tongue; but the teeth are inserted, in two rows of organs like the sting of a bee, in the substance of the trunk itself. The predacious Pectinibranchs are arranged according to the form of teeth on the tongue-ribbon.

Foremost in rank and beauty among the Gasteropods, stands the

Family MURICIDÆ,

or Rock-shells, in which the lingual ribbon is long and narrow, with a multitude of very small teeth arranged in rows of three, (1·1·1,) each of them with several spikes. The middle row only is fixed. In *Murex*

proper, the animal, as it increases in size, periodically produces beautiful foliations or *varices* from its mantle, at least three on each whirl. In the typical species these are thin, light, and armed with numerous, often very long spines; and the canal which holds the breathing siphon is greatly produced, nearly closed, and also armed with spines. One would think the animal would be as much incommoded by its splendid dress as a fashionable lady in a crowded ball-room. As the the animal grows, it eats away the last year's varix, which would otherwise close up the aperture. It often happens that old mollusks, either to lighten the weight they have to carry on their backs, or from becoming more portly inside, eat out part or the whole of the interior partitions in the same way. If the spire is long, or they are attacked by borers in the upper region, where the liver works, they also have the power of partitioning off the unused or diseased part by septa, which, however, are not regular or perforated as in the Nautili.

When the shells are strong, and the varices numerous and foliated, they are called *Phyllonotus*. They are very numerous and beautiful on the west coasts of tropical America and Africa. The shells of *Pteronotus* have a few wing-like varices. When these are feebly developed, as in *Muricidea*, they pass into the next genus, *Trophon*, where the varices have degenerated into mere raised laminæ. This is an arctic form, both of the northern and southern seas. The *Typhis*, which appears first in the older Tertiaries, is a *Murex* with a single open spine between the varices. This is supposed to perform the function of an excurrent canal, like the slit in *Pleurotoma*, or the hole in *Vissurella*. Another group, of which the Spindle-shells are the type, has no varices at all; but both the spire and canal are greatly elongated. The true *Fusus* is a tropical form; but an intermediate group, with moderate canal, (*Chrysodomus*,) abounds in the arctic seas. The *Chrysodomus antiquus*, still common in the British seas, and found in the whole circumpolar region of the North, was equally common in the various tertiary epochs of the English Crag. A reversed variety ("*Fusus contrarius*") was the characteristic species of the Red Crag, and is now found living, beyond the limits of the normal form, in the Mediterranean and on the cost of Spain. The Scotch call it the "roaring buckie," from the "sound of the sea" which the air makes along the spiral passages when held to the ear. The Zetlanders hang it flat, put a wick in the canal and oil in the body whirl, and make a lamp of it. It is now fashionable to suspend the great Turbo in the same way as a flower vase. The *Clavellas* have curiously deformed mouths, and abounded in the Eocene age.

Lamarck, knowing little of the animals, divided his families according to the length of the canal; but this is no index to the length of the siphon. In the *Pisania* group, the canal is very short, but the siphon is moderately long and curled back over the shell in walking. A tooth on the body whirl, marking off the top end of the mouth, shows the position of the excurrent canal. The *Enginas* are little shells with wry mouths, about which very little is known, though they are very common on both shores of tropical America.

As *Pisania* represents in this family Lamarck's *Purpurids*, so *Cominella* and *Metula* represent his *Buccinids*. They are in fact *Buccinums*

with a Muricoid operculum. Their favorite haunts are the rocky shores of South Africa, Australia, and New Zealand; *Metula* being an American and East Indian group.

In the same way *Anachis* represents the *Columbellas;* from which the shell is known simply by having a more elevated spine and transverse ribs.

Family Buccinidæ. (*Whelks.*)

The genus *Buccinum* of Linnæus contained all the shells with a notched base: a heterogeneous group, most of which have been moved off, step by step, to other families and genera; leaving only a few species, mostly from the boreal seas in each hemisphere, to keep up the ancient family name. The Whelks are very closely related to the Murices, from which they differ chiefly in having a thin, oval operculum, with the nucleus a little out of the centre. The true *Buccinum* has a notch for the breathing tube, and *Strombella* (a shell common in the Norwegian seas, but still so rare near England that good specimens sell for ten dollars) a short canal. The *Columbellæ,* which are very pretty little shells, extremely abundant in both oceans of tropical America, are still but little known in their economy, but belong by operculum to this family. They have their mouths so twisted by teeth, that the foot and operculum has to go in and out sideways. Perhaps this accounts for the operculum being so often broken and abnormally repaired. It is a curious fact that whatever be the form of the operculum in the different tribes of predacious mollusks, whenever it has been broken and has to be repaired by the animal, it always takes a simple oval shape with concentric layers, the nucleus being in the middle. In one place on the English coast there is found a race of *Buccinum undatum* (the common whelk of the English and American coasts) which perpetuates a very abnormal condition. They have two small opercula of more or less irregular shapes, but each of concentric elements. Probably their remote ancestor met with an accident, and has transmitted her mode of repairing the fracture to her descendants.

Family Pyrulidæ.

The shells of this group run into those of *Fusus* by insensible gradations; but the animals present a well-marked difference. The neck (not the snout, as in the Strombs) is very long, the proboscis being still further extensile. The head and tentacles are small in proportion. Many of these shells are very large. The *Pyrula melongena* and *P. patula,* inhabiting respectively the Atlantic and Pacific shores of tropical America, are eaten by the natives. In the genus *Hemifusus* are two of the largest living Gasteropods, the *H. colosseus* and *proboscidalis* of the East Indies.

Family Purpuridæ.

The animal of *Purpura* differs very little from that of *Buccinum* and *Murex;* but the operculum is formed on a very peculiar plan. Outside

it looks shapeless, like a chip of rosewood; within, however, it is seen that it has been formed on the usual concentric plan, but with the nucleus elongated, and turned towards the outer lip of the shell. The name of the principal genus is derived from a crimson dye which many of the species exude when pressed. It was not, however, from these, but from the *Murex brandaris* and *M. trunculus* of the Mediterranean, that the ancients obtained their celebrated Tyrian purple. Cavities in the rocks, with heaps of the broken shells, where the mollusks were sacrificed to dye the robes of the nobles, are still seen on the shores of the Morea and Levant.

The shells of this group reproduce many of the forms of the Muricids, but with the chip, instead of the claw-shaped operculum. Thus *Cerastoma* has regular varices like *Murex* and *Vitularia*; irregular ones like *Trophon*. *Rhizocheilus* has generally been confounded with *Muricidea*. *Chorus* presents the shape of *Chrysodomus*, and *Rapana* of *Pyrula*. *Iopas* takes the place of *Pisania;* the wry-mouthed *Ricinula* of *Engina;* and *Nitidella* represents *Anachis* and the *Columbellas*. The true *Purpura* has a peculiar scooping out of the pillar-lip. This, when exaggerated, and at the same time the body whirl greatly enlarged at the expense of the spire, produces the common *Concholepas* of the Peruvian coast, which at first sight might be taken for a limpet. In *Monoceros*, a genus almost peculiar to the west coast of America, and ranging from California to Cape Horn, a sharp spine is developed at the base of the outer lip. The same is seen in *Chorus*, *Cerastoma*, and *Concholepas*; and may be looked upon as a west American peculiarity.

In the *Rapana* group, *Melapium* represents the *Pyrula melongena*, and the delicate *Rapa* shells the *Ficulas*. The *Pseudoliva* is clothed with a coarse epidermis, and has a channel running spirally outside the base of the shell, the use of which is not known. In the angular *Cuma tectum* and in *Purpura columellaris*, there is a hump which runs along the middle of the pillar lip.

The purple-shells frequent rocky shores all round the globe, and are generally very prolific. They feast on bivalves, periwinkles and other shell-fish. Some of them are very sedentary in their habits, especially the *Rhizocheils*, which clasp round the stems of corals and prey upon the Polypes. These often have the breathing canal almost rudimentary.

The *Magilus*, which used to be considered an Annelid, and afterwards a Vermetid, is perhaps a degraded member of this group. When young it has a white, globular shell, shaped like *Natica*. It establishes itself among the Red Sea Polypes; and as the corals grow upwards, so does the *Magilus*, forming a solid, irregular tube, with a keel to represent the canal. *Leptoconchus* resembles its young state, but with a slight notch, and no operculum. The *Magilus*, having plenty of lime to eat, fills up its spire and the forsaken part of its tube with solid shelly matter.

Family Nassidæ. (*Dog-whelks.*)

The *Nassas* have small, compact, highly sculptured shells, with a sharply twisted notch, through which the long curly siphon protrudes. There is generally a strong lump on the inner lip. The animal has

two slender tails at the end of its foot, and a very thin, horny, triangular operculum, very finely serrated on each side. When the operculum is reproduced after injury, very few serrations are formed. In the *Phos* group, there is only one tail, the eyes are very near the tips of the tentacles, and the operculum is claw-shaped, without serrations. The animal and even the operculum is as yet unknown in many of the genera and most of the species of this group: and it is probable that the family will need considerable revision.

In *Bullia*, a genus which delights in southern peninsulas, the foot is extremely large, giving a glossy coat to the shell, and the animal is blind. It probably plows the wet sand for bivalves, like *Natica*. The *Pseudostrombs* form a transition between these and the ordinary forms, not having any gloss on the spire. The true *Nassas* are active burrowers, curling their nose-pipe up through the twisted notch, while they search the sand for bivalves. They are extremely abundant in tropical seas, both in species and individuals. In *Desmoulea* the shell is rolled up almost into a ball; and in *Cyclops*, it is curiously distorted and flattened like a Nerite. Several of the shells called *Nassas*, as the common "*Buccinum obsoletum*" of the west Atlantic, and *Nassa panamensis* of the east Pacific, have a Pisanoid operculum. They perhaps belong, with *Northia*, to the *Phos* group. The *Phos* shells are very beautifully cancellated: they have a sharp plait near the breathing notch, and a wave at the base of the outer lip. *Nassaria* represents the Tritons in this family, and *Cyllene* the Volutes.

The *Eburnas* are very beautifully spotted shells, strong, solid, and more or less shining. They are always smooth, and rarely display any epidermis. They form a transition to the Harps.

Family Pusionellidæ.

This little group has shells like *Fusus*, but the operculum is subtriangular, with the nucleus on the inner margin.

Family Turriculidæ,

These creatures would be taken for *Mitras* from the shell alone. Indeed the only characters by which the shells can be distinguished are the trifling ones that they are externally ribbed transversely, and the outer lip furrowed within; characters which in other groups would only amount to specific difference. Here, however, they are coördinate (so far as yet observed) with important characters in the dentition; the true Mitres being toothed like *Fasciolaria*, which will be presently described; while the *Turriculæ* agree with *Murex*.

In the remaining family of this group, the foot is greatly developed, causing a more or less glossy secretion over the whole shell.

Family Olividæ. (*Olives and Harps.*)

When the foot is very large, we often find the operculum very small or absent. In the Harps and Olives, the foot is deeply chiseled on each side of the front; so as to make lappels, which may be doubled up over

the head to protect it as it burrows in the sand. There are three divisions in the family, of which the types are *Oliva*, *Ancilla* and *Harpa*, and are thus characterized:

Olivinæ. Shell compressed, smooth: pillar plaited: suture channeled: a tail from the side of the mantle occupying the groove.

Ancillinæ. Without shell channel and mantle tail.

Harpinæ. Shell ventricose, with varices pointed at the suture.

The Olives are among the best known and most beautiful of shells. They are found plentifully in all tropical seas, especially in the islands of the Indian and Pacific oceans. They are fond of burrowing in wet sand in quest of bivalves; and can dart through the water with tolerable rapidity, by expanding and flapping their fleshy foot. They are very rapacious; and the larger kinds are fished by hooks baited with flesh. The shells are heavy, painted in beautiful patterns and highly polished. The colors are often very variable in the same species; and as the shape of the shells is generally pretty uniform, there is great difficulty in discriminating several of the kinds. The pillar-lip is not plaited, as in the Volutes and Mitres; but there are numerous spiral folds, of which the foremost unite and travel round the base of the spire, forming a band of different color.

In the *Olivellas*, which are all small shells, living in vast shoals on each side of tropical America, the spire is elevated and the mouth expanded at the base. The foot is not so large; and the typical species have a very small operculum, which is however wanting in *Lamprodoma*. In *Agaronia* the shell is even wider, and very thin. The back is destitute of polish, and is therefore not so much immersed in the foot. It frequents the west coasts of America and Africa, and is found in the Eocene strata. In *Scaphula* the shell is distorted by an enormous lump at the suture.

The *Ancillas* are polished shells, generally of a uniform white, fawn, or brown color, without pattern. They are particularly plentiful in Africa, and in the Eocene strata. In *Dipsaccus* which has, and *Sandella* which has not, a winding umbilicus, the spire is elevated, and the spiral band round the base of the shell ends in a rudimentary tooth. In *Anaulax* the shell is not polished outside, and the shell is thin and wide-mouthed, like *Agaronia* in the last group.

The Harps form a small but well-marked group; of which the species are so like each other that even the Messrs. Adams did not attempt to subdivide them. They all have ventricose shells, with varicose ribs at regular intervals, which may be sharp or flattened on the same specimen. They are painted brown in beautifully penciled patterns, with shades of pink and white; and on the pillar is a large callosity, formed by the olive-like foot of the animal. It is said that the creature will part with its tail, rather than be caught; after the manner of the Italian lizards. In the London Clay is a curious fossil, the "*Buccinum stromboides*" of authors, which forms an interesting transition between the Harps and the *Ancillas*. It has only rudimentary varices; but their pointed tops remain. The general shape, and the lump on the pillar, formed by the animal's foot, which is too large to enter the shell, show close relations with the true Harps.

The teeth in all the families thus far enumerated are formed on the Whelk type, in rows of three each; of which the central one is broad and fixed, while the side ones are movable. All three are armed with variously shaped hooks. In the next group of families, the lateral as well as the central teeth are fixed; and the shell always has folds on the pillar.

Family FASCIOLARIADÆ. (*Tulip-shells and Mitres.*)

This family embraces two very different looking groups of shells, of which *Fasciolaria* and *Mitra* are the types. They agree however in a very peculiar dentition. The central teeth in each row are very small; but the lateral ones are long, narrow, and armed with points like a saw. The tulip-shells are not very strong, generally knobbed outside, with the breathing canal a little curved. They are known from *Fusus* by a few very slight and slanting folds on the pillar, close to the breathing pipe. The *Fasciolaria gigantea* of the South Carolina seas is sometimes two feet in length, rivaling in size the great *Hemifusi* of the East Indies. Small specimens greatly resemble the *F. princeps* of the west coast, but are at once distinguished by the sculpture on the operculum of the latter. The group called *Fulgur*, which abounds on the Atlantic shores of North America, with the East Indian group *Tudicla*, were formerly reckoned with the *Pyrulas*. Whether they have a whelk-like dentition, or whether they are *Fasciolarias* with undeveloped plaits, cannot be told till their animals have been dissected. Whether it speaks well for the zeal of American naturalists that these large species, which can be so easily examined, should be abundant in collections, as far as the shell is concerned, but as yet undescribed from the living animals, must be for others to determine.

In *Latirus*, the shell is shaped like *Fusus* or *Pisania*, but with a few parallel plaits. In *Peristernia* these evanesce, as in *Fulgur;* and some species can hardly be known from *Pisania*. In *Leucozonia*, there is a spine in the outer lip, as in *Monoceros*. The stout claw-shaped operculum, which characterizes this tribe as well as the Muricids, at once distinguishes the shell: but Lamarck's error has been repeated by many authors, and even by Chénu.

The genus *Fastigiella* is known only by its shell; which seems to represent the Cerites among the *Fasciolarias*. The plaits are obsolete.

The *Mitra* group have always been great favorites. They generally have slender, pointed shells, with elegant sculpture and particularly brilliant painting. There are a great multitude of species, but most of them are rare. They have a love for an insular life; being found in great abundance in the islands of the Indian and Pacific oceans, while the shores of the neighboring continents have only a few, and those plain species. The Atlantic ocean is not their favorite: even the choice islands of the West Indies only boasting of a few dull species. The pillar lip is always strongly plaited, the top plaits being the strongest. They are remarkable for doubling up their little foot longitudinally, when they draw themselves in. The operculum is generally absent. They have the power of emitting a very nauseous odor when disturbed. Their proboscis is enormously long, out of all

proportion to the size of the animal. It is difficult to say where they find room to deposit it when swallowed. Swainson, who, with many fancies, devoted much time to pointing out the analogies among various groups of mollusks, paid particular attention to the Mitres. It has already been shown that one group passes into the Muricid. Another possesses the dentition of the Volutes. In the restricted group, the *Strigatellas* have the aspect of *Columbella*. They are found under stones at low water, and are generally covered with an epidermis. Even when living, they are often coated over with nullipore, an evidence of their sluggish habits. The *Imbricarias* are, as it were, plaited cones, and *Cylindra* has the shape of the Olives. They live in the sheltered sands of the coral lagoons, and even in the black mud of mangrove swamps. Lastly, the fossil genus *Volvaria* has close relationship with *Marginella*.

Family TURBINELLIDÆ. (*"False Volutes."*)

The Turbinelles are known from the last family by the lateral teeth of the lingual ribbon; which, instead of being saw-shaped, have only one strong horn on each to tear with. The middle tooth, however, is very long and trident-shaped. The shell always has strong, transverse plaits in the middle of the pillar lip. The true *Turbinelli* are pear-shaped, with a long canal. The "shank-shell" is carved by the Cingalese; and when found reversed is considered sacred. The priests make use of it to administer their medicines. The group *Cynodonta*, of which the two finest species inhabit the tropical shores of Atlantic and Pacific America, are compact, and somewhat triangular in form. The shell looks as if it bid defiance to all enemies, being extremely strong and heavy, armed with stout knobs, and closed with a thick twisted operculum. The animal, however, is said to be timid and inactive, shrinking quickly within its shell at the slightest alarm.

In the next section there is only one row of teeth on the lingual ribbon, the lateral series being obsolete. The central teeth have generally three lobes, but sometimes they end in a single spike.

Family VOLUTIDÆ. (*Volutes.*)

The Volutes are large, showy shells; most of them rare, and highly prized by collectors. They have a very short spire, with a mamillated nucleus, which is sometimes disproportionately large. The bottom of the pillar lip is always plaited, with a notch for the breathing pipe, which is short, turned back, and often furnished with little flaps at the base. The foot is generally large, sometimes with a slit on each side near the head, as in the Olives. The tentacles are small, far apart, and joined by a veil. The eyes are on lumps behind the tentacles.

The Boat-shells and Melons are large and thin, with very expanded mouth, and a few sharply-cut pillar-plaits. They are, as it were, Marsupial animals, the eggs being hatched within the mother's body, and the young ones living there till they are more than an inch long. The *Cymbas* are almost exclusively West African shells. They were called *Yet* by Adanson, who tells us that the high winds some-

times drive shoals of them on shore, where they are eaten for food. They have a very large, irregular apex, surrounded by a keeled channel, and a twisted pillar. The *Melos* are brightly painted shells from the East Indies, often with a pretty crown of spines around the short, smooth spire. In *Volutella* (a tropical American shell) the expanded mantle deposits a coat of enamel over the spire, which is often produced into a long horn. *Voluta* (proper) has a small operculum, and numerous secondary plaits. The typical species, from the West Indies, is beautifully painted with a pattern resembling the staves of music. The commoner species belong to the group *Aulica*, in which the shell is generally tuberculated, with a sharp outer lip. In *Scaphella*, a southern form, also found fossil in the English Crag, the shell is narrow and elongated. In *Fulguraria*, the shell is striated, and the foot is comparatively small. In *Callipara*, the shell is like a young cowry, with very small plaits. In *Lyria*, the shell is shaped like *Marginella*, with very small plaits, and ribbed exterior. It is the only form of volute found on the west Coast of America.

The family of the Volutes make their first appearance in the cretaceous epoch, but very sparingly. In the tertiary groups, particularly the Eocene of the London and Paris basins, a peculiar form abounds, called *Volutilites*, in which the spire is sharp, as in *Mitra*, and the plaits are often very faint. A single recent specimen of this group was dredged in 132 fathoms of water, off the Cape of Good Hope, during the voyage of the Samarang.

Another group differ remarkably from the true Volutes in the shape of the central teeth. Instead of having two large lobes on each side of the small central one, they have only one central spike; which rises up so sharply from its arched support, that when arranged over each other on the tooth-ribbon, they present the appearance of a keel. There is no character in the shell by which the *Amoria* can be safely separated from the ordinary Volutes. In the few specimens examined, the surface is polished, and there are five oblique pillar-plaits.

The same lingual detition is found in the little *Volutomitra grœnlandica;* remarkable as representing an essentially tropical type on a boreal shore. The animal and shell are shaped for the most part as in *Mitra,* from which the teeth are essentially different: so that it may be either considered the representation of the Volutes among the Mitres; or, as placed by Dr. Gray, the mitred element among the Volutes.

Family Marginellidæ.

The *Marginellas* are a numerous group of very pretty little shells, great favorites with collectors from their high polish, and beautiful colors. They are almost all from the tropical seas, and the largest number of finest species are from Africa. If we judge by the shells alone, they form an exact transition from the Volutes to the Cowries; in their plaited pillar and general shape resembling the former, in their glossy coat and thickened lip the latter family. Indeed the transition-genus *Erato* is placed by systematists sometimes in one, sometimes the other group. But so far as the animals are yet known,

they are widely dissimilar. In dentition, they are nearly related to the Volutes, having only a central row of teeth. But these, instead of having three lobes, or a spike, are very broad, with nine small serrations. The proboscis is short, I think; the siphon without auricles; and the foot is folded up longitudinally, as in the Mitres. They further differ from most of the Volutes in their high polish, caused by the sides of the mantle folding over the shell. Sometimes it deposits a large callosity on each side of the mouth.

In the typical *Marginellas*, the spire is distinct; the siphonal notch is not sharply cut out as in the Volutes; and there are five distinct plaits on the pillar. They inhabit clear sands, in somewhat shallow water, and glide along with great rapidity. In *Persicula*, the spire is concealed; the pillar has numerous plaits; and the outer lip has an excretory notch, and is generally grooved within. In *Volvarina* the shell is very thin, scarcely thickened at the lip, and with very small plaits on the pillar. Several small species of this group are common in the West Indies. A group of small shells, called *Closia* by Dr. Gray, are extremely like *Cypræovula* in shape. The outer lip is toothed, and the inner has two large and two small plaits.

In the next group of families, the teeth are arranged in rows of seven each; the central an inner lateral teeth being fixed, as in *Fasciolaria;* but the two outer teeth on each side being movable. The inner teeth have numerous serrations on the edges. They are generally very small and transparent; but the animal makes up for their minuteness by having a strong prehensile collar at the end of the trunk. In this are inserted a number of horny plates, armed with numerous rows of conical teeth.

Family Cassidæ. (*Helmet Shells.*)

The true Helmets are large, handsome shells, somewhat triangular in form, with very short spire, narrow mouth, toothed on each side, and the canal suddenly twisted backward. Like the *Murices*, they leave a varix outside the shell at every period of growth; which, in this genus, occurs at every two-thirds of a revolution. The animal has a large strong foot; and the mantle deposits a very thick pillar-lip, the edge of which projects so as partially to conceal the spire. As the shell grows, the twisted canal is covered over by the advancing pillar lip, leaving a cavity behind. The creatures are active and voracious; crawling, with their stout helmet *behind* their heads, (a fashion which ladies have sometimes imitated,) and their nose-pipe bent back over it, along the sandy flats where the unconscious bivalves quietly wait to be eaten. The inner lip consists of various plates of enamel, which lie in alternate colors. Artists have taken advantage of this to carve cameos; which are produced by cutting the figure in one of the layers, and leaving the groundwork in the next. The large cameo-shell, called by Lamarck *Cassis madagascarensis*, is a native of the Bahama Islands, whence large quantities are brought to the Liverpool market. Dead shells have been dredged by Dr. Stimpson off the coast of North Carolina. The colors of the cameos differ according to

the species of the shell. The operculum of *Cassis* is very long and narrow, like that of the *Buccinum* drawn out; but in the swollen helmets (*Bezoardica*) it is shaped like an expanded fan, with the nucleus on the inner margin. The shells of this group seldom make a varix except when mature; and the pillar lip is thin, seldom plaited. In *Levenia* (peculiar to west tropical America) the outer lip is sharp, but thickened within; the operculum being very small, to suit the contracted aperture. In *Cyprœcassis*, there is no operculum; the mouth is narrow and toothed on each side like the Cowries; and the inner lip is very thick, but not projecting as in the true helmets. In *Cassidaria*, (a genus almost confined to the Mediterranean,) the shell is like *Bezoardica*, but the canal is only partially bent back: in *Sconsia* it is not bent back at all. In *Oniscia*, the canal is straight, and the inner lip wrinkled: while *Pachybathron* is even more like a Cowry than *Cyprœcassis*, having the mouth toothed as in *Trivia* with a notch at each end. The Helmets first appear in the Eocene tertiaries; but their maximum development, as in most other predacious Gasteropods, is in the existing age.

Family Doliadæ. (*Tun Shells.*)

The Tuns are nearly related to the Helmets, both in animal and shell. The latter is always very thin and ventricose, with spiral ribs, and a sharply notched aperture. The animal is large, with a very capacious foot, truncated in front, which it swells out with water when swimming. The head is thick, with the eyes on little stalks at the base of the tentacles. The proboscis is stout and long, and armed with a powerful prehensile collar at the end. The breathing canal is turned back, as in the Helmets. In *Dolium*, the mouth of the shell, is very wide and open: in *Malea*, it is curiously contracted, with ribs on each side. The *Malea ringens* is a very characteristic shell of Pacific tropical America. Its fossil remains, discovered by Dr. Newbery on the Atlantic coast, prove that the two oceans have been separated since the creation of the species. The Tuns make their appearance in the Miocene age.

Family Tritonidæ. (*Trumpet Conchs.*)

The *Tritons* were naturally associated with the *Murices* by conchologists; the only differences observed in the shells being purely artificial, viz: that in *Murex* the varices (or old mouths) are any number from three to thirteen; while in this family they are two or one and a half. This trifling distinction, however, is found to be coördinate with an essential difference in the dentition; the *Tritons* being in that respect closely related to the Helmets and the *Naticas*. They differ from the previous families in having but a small foot, and a nearly straight siphon, inclosed in the canal of the shell. They are almost confined to tropical seas, and have a much greater love for the old world than the new. All the shells of the family have the outer lip toothed within, and most of them have the pillar lip similarly ornamented. The operculum is generally as in the Muricids.

The large *Triton Tritonis* of the Pacific ocean is a great favorite with the South-Sea islanders, who make a hole near the tip, and then use it as a speaking trumpet. A very similar species (*T. nodiferus*) inhabits the Mediterranean, and has been know to crawl to the confines of the British seas. One of them was kindly given by the ancients to the Sea God, to make his commands better heard: and the poet sings of the old Romans,

"Buccina jam priscos cogebant ad arma Quirites."

The varices appear on every three quarters of a whirl, giving the shell a somewhat distorted appearance. In the subgenus *Gutternium*, the canal is very long and straight, as in *Murex* proper. It is generally of moderate size, and somewhat twisted. In the fusiform species with a long spire, the canal is very short. Sometimes there are no varices till the shell approaches maturity. There is one group (*Argobuccinum*) in which the shell is thin and whelk-shaped, and the varices irregular or absent. It is characteristic of the west coast of America; the *A. nodosum* being found in the tropics, the *A. scabrum* along the foot of the Andes, the *A. cancellatum* in the extreme south, and the very similar *A. oregonense* in the northern districts. These, with a large proportion of the true Tritons, are covered with a very thick, loose, and generally hairy epidermis.

The *Personœ*, or Mask-shells, are Tritons with a broad thin inner lip, and curiously twisted mouth; being to *Triton* what *Malea* is to *Dolium*. The *Euthriœ* are regarded by Dr. Gray as Tritons without varix. The shell appears related to *Clavella* or *Peristernia;* but the teeth of the animal have not yet been examined.

The *Ranella* group are very pretty shells, having a row of ornamental varices running up each side of the spire. In the typical species, the operculum is shaped as in *Murex* or *Pisania*. But in *R. crumena* it is formed as in *Pusionella*. This caused Dr. Gray to remove it to the *Cassis* family, supposing that all the shells with round varices had the usual operculum, and all those with sharp-edged ones (*Eupleura*) the abnormal one. Having examined however a number of specimens of the sharp-ridged *Eupleura nitida*, collected by Professor Adams, at Panama, with the opercula in situ, I find that they belong to the Buccinoid type, being oval and annular, with the nucleus near the anterior end of the outer lip. This family appears sparingly, like its congeners, in the Eocene strata. A curious fossil genus, *Spinigera*, from the Inferior Oolite, is intermediate in characters between the spiny-variced *Ranellas* and *Rostellaria*, and may have belonged to either family.

Family Cerithiopsidæ. (*False Cerites.*)

A group of very small shells were separated from the Cerites, by Professor Forbes, on finding that they had a retractile proboscis, and a muricoid operculum. They inhabit all seas which have been properly searched; living in sheltered places near the shore among seaweeds and zoophytes. The largest of them scarcely exceeds an inch in length, and one-eighth in breadth. They are all highly sculptured,

with stout knobs or keels, and are very beautiful objects under the microscope. The teeth of *Cerithiopsis* are said to resemble Triton; but the tentacles are more like those of *Tornatella*. The siphon-pipe is extremely short, not protruding beyond the notch of the shell. In *Triforis*, the whirls turn the wrong way, and the lip of the shell is often twisted into pipes for the reception of the breathing and excurrent ducts. The third pipe behind, which gave the name to the genus, is simply the relic of a former mouth. The shells in each group are sometimes so like each other that they can scarcely be distinguished, except by the direction of the whirls. Yet the animal of *Triforis* is said to belong to the true Cerites.

?? *Family* Cancellariadæ.

The true position of this family is not yet ascertained. The *Cancellarias* are singularly beautiful shells, always elegantly sculptured, with a few small plaits on the pillar, which are sometimes obsolete. Often the pillar is hollow; and instead of a notch or short canal for the breathing tube, there is only an angular pinch in the shell. The siphon pipe is extremely short; but as to the important characters of the head, the learned differ. Messrs. Adams say that it has neither tongue, teeth, nor proboscis; and Deshayes states that it is a vegetable feeder. Dr. Gray, however, places it near the Muricids. The genus is confined to tropical seas and rather deep water; but an allied form, *Admete*, lives in Greenland, and visits the New England shores. In the boreal group *Trichotropis*, so called from the beautiful hairy fringes on the epidermis; there are no plaits on the pillar. The animal has been described by some authors as having a retractile proboscis; by others as having a muzzle. Whether widely different animals have been grouped together, or whether great mistakes have been made, remains to be seen.

In the foregoing families, when the shell has been partially covered, it has been not by the mantle (as often stated) but by the broad and fleshy foot. In the aberrant family of Fig-shells, however, the foot, though widely extended, is very thin; and the shell is partly enveloped by two flaps of the mantle, as in the Cowries.

Family Ficulidæ. (*Fig-Shells.*)

The shells of this group are singularly elegant; very thin, pear-shaped, finely cancellated outside, with a long wide canal, which protects the still longer breathing pipe. The animals are beautifully painted, with markings of various colors. They stretch out their long white necks, with flat heads, and large black eyes, and crawl very rapidly over the sands. There are very few species; one inhabiting the Pacific shores of tropical America, another the Atlantic, and the rest the East Indian seas.

We now come to animals having a very different appearance, and furnished with shells having no similarity in shape with those hitherto described. The shells were associated by the conchologists with the

Nerites, with which they really have scarcely even an external affinity. The creatures are very voracious, armed with a retractile proboscis, and furnished with teeth constructed like those of *Cassis* and *Triton*. They have, however, no breathing pipe, the water being conveyed to the gills by a fold in the mantle. The shell consequently has no notch at the pillar, and the operculum (when present) is spiral.

Family Velutinidæ.

This is a little group of creatures chiefly from the northern seas, with very thin, slightly spiral shells, ending in large round mouths. The mantle of the animal partly covers the shell, as in *Ficula*. The *Velutinæ* live in deep water in the Eastern Atlantic; *Morvillia* in the West. In *Marsenina* the shell is ear-shaped, (as in *Lamellaria;*) and in *Onchidiopsis* it is simply a horny layer.

Family Naticidæ.

The *Naticas* are very queer creatures; exceedingly voracious, and yet generally blind; armed with the usual carnivorous appendage of retractile proboscis and horny jaws; and yet, as they walk, looking more like a lump of fleshy sand than a predacious Gasteropod. Their shells are strong, beautifully formed, and very innocent looking; having a short spire, hollow pillar, and round mouth. The operculum is slightly spiral, and is generally horny; but sometimes has a shelly coat outside. The great peculiarity of the animal is its enormous foot, which not only envelops the shell, like a mantle, but is doubled up in front so as to form a wedge-shaped digger, with which it plows up the wet sand. The head is hidden behind the plow, and thus protected from the sand; and as the eyes would be hidden also, they are dispensed with. The two largest species of the group are found, one in New England, the other on the Oregon shores. No sooner does the tide go down than they may be seen plowing just below the surface, in the region where bivalves love to hide, a small portion of the shell just protruding over the moving sand. No sooner do they come in contact with an unhappy *Tellen*, than the plow and the broad foot envelop it, the head stretches out, the trunk is darted out, and the drilling process commences, which ends in the suction of the unfortunate bivalve.

Those who examine the objects on the sea shore in summer time can hardly fail to have noticed some curious sandy, ribbon-shaped, frail substances, curled like a horseshoe. Naturalists have often taken them for zoophytes; and they have been variously described as *Flustra arenosa*, *Eschara lutosa*, *Alcyonium arenosum*, and *Discopora crebrum*. It is however nothing but the nest which Mother Natica makes for the protection of her eggs. If held to the light when wet, it will be found to consist of sand, glued together, and filled with little cells arranged in quincunx, each one of which has contained an egg. The *Naticas* are found in all parts of the world, and have existed in all ages, beginning with the palæozoic.

In *Natica* proper, the operculum has a shelly coat, which is often

spirally grooved. The umbilicus (or pierced pillar) is generally spiral, leaving a lump on which the apex of the operculum lies when open. The remaining genera have horny opercula. The northern species mostly belong to the group *Lunatia*, with straight umbilicus and small pillar-lump. In *Neverita*, which is found in subtropical regions, the spire is flattened, the mouth wide, and the umbilicus winds round a lump which more or less fills it up. This lump is sometimes grooved. The shells of *Polinices* have the spire conical, and the umbilicus nearly covered by a very large flattened lump: they are white, or only slightly tinted. *Ampullina*, of which only one species is living, the rest abounding in the Eocene, has a ventricose shell, with the axis not perforated. It is polished by the very large foot, and there is a large lump on the pillar. *Naticella* has a thin, open shell with very small umbilicus, almost covered by a narrow, dark colored deposit. In the form of the shell, it passes into *Sigaretus*, in which the shell is flattened, sometimes ear-shaped, and partially concealed by the animal. The outside, however, is striated, not polished as in ordinary *Naticas*. The operculum is very small, and the animal sluggish and timid. *Naticina* is intermediate between *Naticella* and *Sigaretus*, having an umbilicus but no lump. *Amaura* is a boreal form, with raised spire and solid pillar.

In the families which follow, the teeth are arranged in different and peculiar patterns. The shells are of very dissimilar shapes; but the animals all agree in having a retractile proboscis.

Family Lamellariadæ.

In this family the foot is enormously large, completely enveloping the shell. There is a slit in the mantle to convey water to the gills. The shell is flat, transparent, or horny. The teeth are in rows of three, as in the Muricids; but the side teeth are very large and trapezoidal. The *Coriocella* is a large black animal, inhabiting the tropical seas. *Lamellaria* and *Ermea* are principally from temperate regions. In *Ermea* there appear to be additional lateral teeth.

Family Scalariadæ. (*Wentle Traps.*)

The Dutch called these shells Winding-Stairs, from the beautiful step-like rings ascending in a spiral. The spire is more or less elevated, with a round mouth and reflexed lip, which leaves a varix at each period of increase. Sometimes the whirls are separated from each other, only adhering by the edge of the rings. This is beautifully seen in the famous *Scalaria pretiosa*, for which the Dutch used to give two hundred dollars, but which may now be bought for one. The animal has a fold in the mantle to convey water to the gills, being the foreshadowing of the siphon-pipe in the canaliculated shells. The foot is extended in front, grooved behind, with a thin, spiral operculum. The head is crescent-shaped, and armed with a strong, fleshy trunk. When disturbed, the creature emits a purple dye. It is very voracious, eagerly devouring putrid meat. The teeth are quite different from those of all other prosobranchiate mollusks, resembling most

those of *Bulla* and *Ianthina*. There are no central hooks. The lateral teeth are very numerous and regular, arranged in lines forming an obtuse angle.

The *Scalarias* are rare, inhabiting deep waters. They are, however, found in all parts of the world, even in the boreal seas. The species are generally very much like one another, and white. The Spaniards at St. Blas wear them as ear-rings, calling them *Caracoles finos*. The shells with irregular varices are called *Cirsotrema*. Sometimes they are almost evanescent; in which case the shell can hardly be distinguished from *Aclis*. Fossil forms, which may or may not belong to this group, are found as early as the oolitic rocks; but true *Scalarias* do not appear till the later cretaceous periods.

The remaining families of this tribe differ from all the previous ones, and indeed from all other known Gasteropods, in having no teeth on the lingual ribbon. In fact the existence of a tongue at all has to be confirmed. They have, however, a retractile proboscis, and probably live by suction. It is said by some careful observers that the *Cancellarias* belong to this section.

Family Eulimidæ, *&c.*

The feet in this family are very short behind, but enormously produced in front; and are used not merely for crawling, but for exploring in advance. The tentacles are slender, with small eyes immersed in their base. *Eulima* has a pointed shell, with flat, glossy whirls, and is generally white. The mouth is like *Melania*, with a very thin spiral operculum. *Leiostraca* is very slender and elongated, with periodic thickenings every half whirl. *Niso* is umbilicated, and often highly painted. Many of the *Eulimæ* have the axis twisted, especially near the apex. This is very much the case in the group *Stylifer*, the animals of which live as parasites immersed in star-fish, or on the spines of sea-urchins. They do not appear to have an operculum. The *Entoconcha* has been found living in *Synapta digitata*.

Family Pyramidellidæ.

These creatures differ from the *Eulimas* in having the tentacles short, broad, and folded together. The foot is not prolonged in front. The operculum has few whirls, and is very thin, generally wrinkled. There is a rudimentary breathing fold in the mantle. All the animals of this family are born with a reversed spire; but no sooner do they commence their independent life than they twist themselves round, and continue their growth in the usual right-handed manner. The reversed nuclear shell is generally found at the tip of the apex, more or less immersed in the first regular whirl, and giving the spire a somewhat truncated appearance: in some species it even projects beyond the sides of the spire. In the typical group, *Pyramidella*, the shell is sculptured with transverse ribs, and the pillar is armed with strong plaits. The mouth is pinched up in the region of the rudimentary breathing hole. The operculum is narrow and notched, to suit the long contracted aperture. In *Obeliscus*, the shell is smooth

outside, and the lip periodically thickened within. The plaits are very strong, often projecting beyond the mouth. Sometimes there is only one stout fold. In *Odostomia*, the sinistral apex is very small, the shell Rissoa-shaped, with one tooth on the columella, which sometimes (as in *Auriculina*) becomes obsolete. In *Monoptygma*, the fold is slanting.* In *Chrysallida*, the shell is strongly sculptured, and the shell contracted at each end. The outer lip in the adult is extremely thin in front, but thickened behind. The species are very numerous on the west coast of America, where they are found in the crevices of dead shells. All these creatures are very minute. The *Chemnitzias* are somewhat larger, a few species actually reaching an inch in length. They are very much turretted shells, with large sinistral apex and melanoid mouth, without plait. Most of the species have flattened whirls with transverse plaits; but in *Eulimella* and *Menestho*, they are smooth. In *Aclis*, the whirls are tumid; and the mouth is sometimes round, like a Scalaria without rings.

Large shells are found in the palæozoic and oolitic rocks, which are referred provisionally to this family; but the characteristic apex can seldom be examined, and their true position is doubtful. In the tertiary strata, we find representatives of most of the living forms.

Very few species in this family abound in individuals, and from their minuteness and rarity they are seldom seen in collections: but very few families boast of so many specific forms. They are more numerous even than *Rissoas*, both in the British seas and in the Gulf of California. Shell sand, especially from deep water, should always be carefully searched for them; and the sinistral apex carefully examined, to distinguish them from *Rissoids*, &c.

Family Solariadæ. (*Perspective Shells.*)

The shells grouped together in the *Trochus* family by Lamarck, are found to belong to five very widely separated groups. The true *Trochus* is a Scutibranch, allied to the Ear-shells and Limpets. The *Trochita* is a Rostriferous Pectinibranch, allied to the Slipper-limpets. The *Risella* belongs to the Periwinkles, in the typical portion of the same group. The *Phorus*, or Carrier-trochus, belongs to the further extreme of the same group, being a scrambler, allied to the Strombs. While the *Perspective Top-shells* are found to possess a retractile proboscis, and to have many points of resemblance with the very differently shaped *Pyramidellids*. The shell of *Solarium* is known by the wide open umbilicus, which has always a crenulated keel within, ending in a notch at the base of the mouth. The shell is top-shaped, with a flat base, and is always beautifully sculptured. The point of the spire is rather flattened, and there may always be noticed a minute hole, even in perfect specimens. This is caused by the nucleus of the shell, which is reversed and globular as in the Pyramidellids, being turned upside

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*This genus was constituted from very different shells. The supposed original type is an abnormal *Ancillaria*. The name is here kept, as by Woodward, for shining, sculptured East Indian shells, intermediate in form between *Odostomia* and *Tornatella*. As the animal has not yet been observed, their true position is uncertain.

down, and inserted, bottom upwards, in the succeeding whirl. The animal has a large foot, with flat, paucispiral operculum, and short tentacles folded sideways. In *Torinia*, the base is rounded, and the operculum is very singular, being *conical*, with many whirls. *Bifrontia* is, as it were, a *Torinia* rolled out flat. Sometimes the whirls scarcely touch. The mouth is square, as in *Solarium*. The genus was constituted from French fossils; but Mr. McAndrew has found it living in very deep water, near Teneriffe, with an operculum and sinistral apex exactly like *Torinia*. The genus *Philippia* consists of smooth *Toriniæ*, with flat operculum. It is said by Philippi to have an animal like *Trochus;* but this is probably a mistake, as the apex is sinistral. *Discohelix* is smooth and flat like *Planorbis:* it is doubtful whether its relations are with *Bifrontia* or with *Vitrinella*. It is found fossil in the American Eocene strata, and living in the Mediterranean.

A large number of fossil genera are referred to this family by Chénu, but their true place is doubtful. Many Trochids have a large crenulated umbilicus, and the characteristic reversed apex can scarcely be observed in the older fossils.

Three families, differing from each other very much in the shape of their shells, but still having many points in common to distinguish them from the ordinary siphon-bearing univalves, have been separated from the rest of the predacious Gasteropods by Dr. Gray, under the name

TOXIFERA.

They have a retractile proboscis: but instead of a separate lingual ribbon, the tube of the trunk is turned in upon itself, and armed with two rows of long barbed teeth, implanted singly in the skin of the fleshy tube. The teeth are curiously formed, resembling the sting of a bee when seen in the microscope; and probably have more vitality than those of the ordinary type. In some species, the end of the tube is large enough to admit the little finger; and the creature is able to inflict a decided bite.

Family Conidæ. (*Cones.*)

The Cone-shells are great favorites with collectors, in consequence of their brilliant painting and regular patterns. The *Conus gloria-maris* has more than once sold for $250. Almost all the species, however, are formed on one plan; and in the living state, the colors are hidden by a skin, which is often very rough and thick. The animal has a short, strong foot, square in front, and with a large hole underneath, through which water is sponged up. It bears a long narrow operculum, of concentric layers beginning from the point: but if it is mended after fracture, the nucleus is in the centre, as in other tribes. The siphon-pipe is long, extended through the notch of the shell. There is always a notch at the other end of the mouth also. The head has two long slender tentacles, with the eyes along their sides. When the proboscis is drawn in, it leaves a funnel-shaped expansion, or veil, in front of the head. This veil is fringed at the end in *Tuliparia*; and

probably also in *Rollus geographicus*, which differs from the rest in having no operculum. The Cones are found in all tropical seas ; but abound most in the Indian Ocean and Eastern Archipelago. Some of the species are very widely distributed, reaching from the Red Sea to Easter Island and the Gallapagos. They prowl in the holes and fissures of rocks, and the winding passages of coral reefs ; where they crawl slowly in depths ranging from low-water mark to forty fathoms. The shells are generally heavy : and as the animal grows stouter, he absorbs the inner whirls of the shell, leaving only a very thin partition. At the same time he preserves his weight by depositing thick coats in the region of the spire. Shells therefore which a "collector" would throw away, may be valuable to grind down and show the inner structure.

The *Dibaphus* is a puzzling shell, intermediate between *Conus*, *Mitra*, and *Terebellum*. Its true position cannot be stated without a knowledge of the animal. Fossil Cones first appear in the chalk : and are tolerably common in the tertiary strata. The *Conorbis* of the London Clay is lozenge-shaped, closely approaching in form some members of the next family.

Family Pleurotomidæ.

In this family the head is truncate, without a funnel. The shells are generally turrited, and are only known from *Fusus* by a slit in the outer lip, near the suture, corresponding with a slit in the mantle of the animal. The typical genus, *Pleurotoma*, has a long canal, and the slit separated from the suture. The operculum is flat, somewhat triangular, with the nucleus near the canal. *Drillia* differs in having a short canal. These forms are peculiar to tropical regions. They are represented in Northern seas by *Bela*, which has a somewhat similar operculum ; but the slit is nearly obsolete, and the pillar is flattened. *Lachesis* has a Mamilated spire, and a Buccinoid shape.

Another group is characterized by the nucleus of the operculum being in the centre of the long side, as in *Pusionella* and *Bezoardica*. In *Clavatula*, the canal is short ; the shell resembling *Drillia*. In *Tomella*, the spire is short and the canal produced ; the shell resembling a *Clavella*, with a wave near the middle of the outer lip. There is a thick deposit near the suture, as in that genus.

A third group has no operculum at all. The *Clathurellæ*, (*Defrancia* of Millet ; the true *Defrancia* being a Polyzoon,) are among the most beautiful of small shells. They are like a *Drillia*, with a deep posterior notch close to the suture ; and the whirls are swollen and delicately cancellated. They are found in temperate as well as in tropical climates. In *Mangelia*, the notch is very slight, and the shell plain ; being in fact a *Bela* without an operculum. The *Citharæ* are a group of beautiful little shells, like flattened Harps. They have regular transverse ribs, notched at the suture : the mouth is narrow and straight, toothed or wrinkled within, like *Oniscia*. Dr. Gray places them with *Cassis*, their true position being of course uncertain till the animal has been examined. In *Daphnella* the shell is thin and ventricose, very finely sculptured, and with the family notch almost obsolete. The shell is closely related to *Metula*, which has probably a Muricoid animal.

The known species in this family amount to at least five hundred. First appearing in the later cretaceous age, they very rapidly became plentiful in the tertiary strata, three hundred species having been already described. But although so plentiful in forms, they are generally, like the *Pyramidellidæ*, rare in individuals ; and collections may often be seen entirely destitute of them. They are generally found in deep water, ranging however from low water to a hundred fathoms ; and culminate in the China seas and in west tropical America.

Family TEREBRIDÆ. (*Augur-shells.*)

The Augur-shells form an aberrant family, in general easily recognized by the very slender and produced spire, with flattened whirls and a deeply-notched aperture. Although several of the species are tolerably large, and very common in the Pacific islands, their anatomy is as yet but little known. This group, like the other Toxifers, has only appeared late in the history of our planet. About thirty species have been found in the tertiaries ; but in the existing seas, fully two hundred species have been discovered. They live in deep water, almost always in tropical climates. So far as known, the teeth and proboscis are like those of other Toxifers, but the foot and head of the animal are very small. The tentacles are close to the mouth, exceedingly minute, and with mere specks of eyes at their summits. Sometimes the eyes and even the tentacles are not to be seen ; and the head is little more than a mouth, as in the shell-bearing Pteropods. The nose-pipe however is very long, and reflected through the sharp notch. The intromittent organ is longer still, like a living thread proceeding from the nape of the neck. There is a small, horny operculum, not filling the mouth, and shaped somewhat as in *Pleurotoma*. The shells are generally glossy, heavy, and prettily painted and sculptured. The upper whirls of the shell are often of chalcedonic texture, the inner cavity having been filled up with glossy shelly matter. In this respect there is a striking contrast between the Augurs and the Screws, which latter group partition off the upper whirls with thin septa. The Screw-shells therefore are often found broken ; while the Augurs are generally perfect. The Augurs are so slender that sometimes as many as thirty whirls may be counted on a shell three inches long but not a quarter of an inch across at the broadest part. It can hardly be believed that the creature can balance his heavy pole, crawling like an ordinary Gasteropod, and supporting his weight on so short a foot at an enormous leverage against him. It is not improbable that he lives in the midst of sandy mud, through which he can easily push his needle and twist round ; leaving the top of his long nose in the water. In such an abode, eyes would be of no service.

It is not yet known how far the differences in the shells are coördinate with those in the animals. Dr. Gray divides the family into those with, and those without tentacles and eyes. From the former he separates a genus *Leiodomus*, in which the suture is callous, like *Bullia;* but the foot is small, not bulky, as in that group. For the present, it is convenient to separate the non-sculptured species as *Subula;* keeping *Terebra* for those with a band near the suture. The

beautiful group *Myurella* has the band nodulous. *Euryta* is a curious group in which the spire is shorter, and the canal so twisted that the pillar appears pierced. The form of these shells offers a transition to *Buccinum;* while a few other species present the aspect of *Cerithium.*

We have now passed under review all the Gasteropods which are known to possess a retractile proboscis. It is not certain that all of these are strictly carnivorous; and it is almost certain that some tribes which have a permanently elongated muzzle are not vegetarians. Between these two great leading divisions of the comb-gilled crawlers, there is a somewhat anomalous group, the true position of which is not yet ascertained. It is strange, (and not, perhaps, very creditable to naturalists and collectors,) that Cowries have been among the commonest shells from the earliest times; abound not only in species, but in individuals; form a regular staple of trade; are found in all warm seas; and yet a reliable account of the anatomy of the animal is still a desideratum. Scientific observers have frequently given accounts of them, and the creatures are figured in many of the great voyages; and yet Dr. Gray asserts that it has a short muzzle, grouping it with the land and sea Periwinkles, while the whole army of ordinary naturalists declare that it has the retractile proboscis of the Whelks. At my request, Dr. Stimpson examined the animal of the large and typical *Cyprœa testudinaria*, which had been brought home by the United States Exploring Expedition; and to our surprise it did not accord with either the one or the other type, but, on the contrary, furnished us with an example of a *retractile muzzle.* The snout, contracted in alcohol, was about half the length of the shell. Instead of being drawn in from the base, as in Whelks, it was drawn in from the tip; The tongue-ribbon was coiled up in a cavity near the stomach. Probably the end of the muzzle protruding in front of the tentacles has been mistaken for the ordinary rostrum.

The teeth of *Cyprœa helvola* are very like those of the land and sea Periwinkles; but those of *Trivia europœa* have no small resemblance to those of *Natica.* The teeth of *Ovulum* are altogether peculiar; whether, therefore, the egg shells are rightly classed with the Cowries, remains to be seen.

Family Cyprædæ. (*Cowries.*)

The Cowry shells, when adult, are nearly globular, not showing any spire, with a narrow mouth, toothed on each side, nearly in the middle of the base; with a deep notch at each end. They are almost always smooth and polished. When young, however, they present a very different shape; being then very thin, with an open mouth, sharp lip, and short spire. At that period they have the general aspect of Olives without the plaits; and, as they never display the same shape or pattern that they do in mature life, they have sometimes been described as different species. The adolescent Cowry curls-round the sharp edge of his mouth, and then begins to make teeth on each of the lips. At the same time, the mantle spreads out, forming two great flaps, one of which envelops each side of the shell, and deposits layer over layer of

enamel, till the proper pattern has been given. A line is generally seen on the back of the shell, where the two flaps met. The Cowries are very pretty animals, with the mantle-lobes generally adorned with fringes or ornamental painting. The breathing pipe is very short, and often fringed also. They have long, slender tentacles, with eyes midway up. The foot is very large, but can be withdrawn, with the mantle lobes, into the shell. The Cowries are shy, and crawl slowly. They hide themselves in coral reefs and under crevices of rocks. They are found in all tropical regions, but there are very few on the American coasts. The difference in this respect between the Pacific shores of America and the Pacific Islands, is very remarkable. On the east coast of South America no species has yet been found.

The Cowries form no inconsiderable an item in trade; the larger species being brought to port in great numbers, for sale as ornaments; while one of the smaller species, *Cyprœa moneta*, is collected (as gold) for money. It passes current in Africa, as the medium of exchange. Many tons are annually brought over from the East Indies and the Pacific Islands, to transport again to the negroes of the Senegambian region. In 1848, sixty tons were brought into Liverpool alone. Cowries were found by Dr. Layard in the ruins of Nimroud. The typical species have a singular excavation near the notch under the pillar lip.

In the pear-shaped Cowries, *Luponia*, this part is irregularly plaited. In *Aricia*, the base is flattened by thick masses of shell, which project over the sides.

In the *Trivia* group, the foot is short in front, but greatly lengthened behind: the breathing canal is long also. The shell is ribbed or covered with pustules; the ribs are carried round the lips, instead of separate teeth; and the pillar is scarcely excavated. All the very small Cowries belong to this group. *Cyprœovula* is intermediate in form between this and the next family; while *Erato* has a shell shaped like *Marginella*, with minutely crenulated lips and polished back. The Cowries first appear in the later cretaceous beds, and are now at the maximum of development.

Family Ovulidæ. (*Egg and Shuttle Shells.*)

As far as the shells are concerned, the *Ovula* may be described as unpainted Cowries without teeth on the pillar lip. The animal also is sufficiently like the Cowry, in general appearance. The teeth however in the only species examined (*Ovulum ovum*) are so unlike that or any other known type, that their habits have probably some great peculiarity to correspond. On each side of the short central tooth, is a tall hooked lateral with jagged edges; and on each side of that, a very large fan-shaped tooth, bordered by a deeply-cut, curly fringe. In *Ovulum*, the outer lip is turned in and toothed: in *Calpurnus*, the shell is hunch-backed, with a curious wart at each end. In *Carinea* there is a ridge across the back, and the lip is not toothed.

But the most singular shell belonging to this group is the *Weaver's Shuttle*, (*Radius volva*,) in which each end of the lip is produced into a very slender canal, longer than the body of the shell itself. The

creature folds its foot round the *Gorgonias* on which it lives, carrying its shuttle gracefully over its head, the edges of the lip and canal being elegantly adorned with tufts. In other species the canals become shorter and shorter till they are only a prolonged notch. The smaller forms are colored differently, in the same species, according to the coral on which they feed. In *Simnia*, the outer lip is quite sharp, and the animal has a long foot and breathing pipe, as in *Trivia*. None of the Cowry or Shuttle tribe have any operculum.

Sub-order ROSTRIFERA. (*Muzzle Bearers.*)

The remainder of the Comb-gilled Crawlers have a longer or shorter snout which is not retractile, and is technically called a *rostrum*. In the Strombs and their allies, the snout is very long, and the teeth are adapted for tearing carrion, on which they live; but in most of the families, they browse upon the herbage. The proboscis-bearing shells are all from the seas or estuaries; but the vegetarian tribes are also found in fresh waters or on land. In the latter case, the gill cavity is changed into a lung. The teeth of the Rostrifers are always in seven series, 3·1·3: but in the first group the lateral teeth are claw shaped, as in *Cassis* and *Natica:* while in the Periwinkle group they simply have serrated edges, adapted for rasping plants. The Rostrifers are arranged by Dr. Gray according (1) to the shape of the foot, (2) to the position of the eyes, and (3) the shape of the gills. The dentition has not been regarded by him of primary importance, as in the trunk-bearers. It is impossible to group them in a straight line so as to show all their known affinities; a few families, as the Strombs, Worm-shells and Apple-snails, appearing to disturb every natural order of succession.

First Group. *Teeth arranged as for animal food.*

Family Strombidæ. (*Wing Shells.*)

The Strombs and their allies are very strange creatures. They are rather leapers than crawlers, and jump about the shore, using their foot as a leaping pole, searching for dead fish and other refuse, of which they are the useful scavengers. The shape of their body is altered to suit their change of habits. As they stretch themselves out of the shell, the body seems made up of scraggy limbs, like a dead tree partially deprived of its branches. The foot, which is a stout, muscular lever, is the trunk of the tree: from this branches off the head, if indeed you can say that there is any distinct head or neck; for it consists, first of a stout truncated branch, which is the long muzzle with the mouth at the end; next of two smaller branches, also truncated at the end; these appear to be tentacles, but are really stout pillars for the eyes to rest in; lastly, of the true tentacles, which are little pointed twigs growing out of the eye-stalks. The second great branch is an arm going off at right angles to carry the operculum. This is long, claw-shaped, and toothed at the edge, only attached to the animal by

a small scar. It serves therefore as a shield when the animal is in motion, as well as a door when it is at rest.

The eyes in the Strombs are remarkably well formed, being (like those of the Cephalopods) more highly organized than in many fishes. They have a distinct crystalline lens, with an iris differently colored in different species.

The shell also is very peculiar. When young, it resembles a cone, with the spire more or less elevated, and a very thin lip. But as it approaches maturity, it spreads out a great wing, which is gradually thickened with layer upon layer from the mantle, till the shell is very strong and heavy, and able to tumble over without injury, as the animal scrambles on the rocky shore. The pillar has a twisted canal for the breathing pipe; and near it is a very deep notch in the outer lip, where the animal can save his head from a blow as the shell falls over. The wing is further notched at the suture.

The *Strombus gigas*, or "Fountain-shell" of the West Indies, fills up the earlier whirls with solid matter, and sometimes weighs five pounds. It is a favorite ornament in consequence of the delicate pink color of the mouth; and is used for cameo-cutting like the Helmets. It is alas! ground to powder wholesale, for the manufacture of the finer kinds of porcelain; three hundred thousand having been imported into Liverpool in one year, from the Bahama islands.

The Scorpion-shells (*Pteroceras*) are like the Strombs when young: but when mature, they develop six or more long claws, variously twisted. In *Rostellaria*, the head-notch is close to the breathing canal, and the spire is long. An excurrent canal generally ascends the spire, and is sometimes long enough to twist over at the apex and come down on the other side. In the aberrant group *Terebellum*, of which only one species is now living, the shell is glossy, sharply truncated at the base, without canal or notch, and with a sharp outer lip. The operculum is very singular, having the appearance of a bird's foot with claws. The creature, when taken from the water, will leap several inches. In one of the Eocene species, the spire is rolled in and hidden; in another, a canal ascends the spire as in the Spindle-Strombs.

The fossil forms belonging either to this group or to *Aporrhaïs* appear first in the Oolites. Nature might seem to have amused herself in the strange and varied shapes which many of them assume, especially in the *Spindle* and *Scorpion* tribes. The true Strombs however barely appear in the tertiary age; at present they culminate, while the other forms are dying out.

Family Phoridæ. (*Carrier Top Shells.*)

Very different in the form of shell, but agreeing in the peculiar shape of the animal, are the Carrier Shells. They live on banks of stones and dead shells, chiefly in the East Indies, over which they scramble, stretching out their foot-pole, with the opercular arm and the long muzzle, like the Strombs. Their eyes however are very inferior, and are placed at the bottom of slender tentacles. They have no breathing tube, the shell being top-shaped. Contrary to the habit of

the Strombs, they all make their shells with a wide rim; but they have the propensity to stick pieces of stone and broken shell to their backs, so as often to hide what they have made themselves. By this means they probably escape detection. In *Phorus*, the pillar is solid, and the operculum thin, concentric, with the nucleus at the side. In *Onustus*, the pillar is open, and the layers of the triangular operculum are piled one upon another.

Family Aporrhaïdæ. (*Spout Shells.*)

These creatures may be regarded as Spindle-strombs, passing back to the ordinary type, with the common eyes and crawling foot. The wing of the shell is always enormously dilated, and often clawed; but no mark has yet been found out by which the numerous fossils of the secondary rocks can be referred to one or to the other group. The two British species, *A. pes-pelicani* and *A. pes-carbonis* have, as their name implies, very wide claws. The New England species has a broad palm without fingers. The breathing canal in all the members of this family is simply a fold in the mantle entirely covered by the shell. The operculum is like that of the Whelks, but the animal is widely different. The *Struthiolariæ* have a simple varix instead of a wide lip. They are peculiar to the Australian seas. A very curious shell, *Halia*, like a marine *Achatina*, has been referred to this group; as also has *Trichotropis;* but we must wait for a knowledge of their anatomy.

Family Pediculariadæ.

The *Pedicularia* is a curious little shell, living as a parasite on coral in the Mediterranean. When young it is spiral, when adult flat and open like *Concholepas*. The most singular point about it is the dentition, which is like that of *Strombus* and *Aporrhaïs* exaggerated. The outside teeth are produced into enormous claws, like the fingers of a bat's wing folded together. In this respect it resembles *Carinaria*. This and the following families are of sedentary habits, either crawling about in crypts and chinks, or remaining absolutely fixed for life. They are very degraded animals, as compared with the noble Strombs; yet their dentition is more allied to them than to the Periwinkles. The fixed shells must of course live on what the water vouchsafes to bring them; why therefore their tongues should be armed with weapons of war it is difficult to say, as the bivalves, which live in the same way, are entirely destitute of them. How much our ignorance is revealed to us by the little knowledge which we possess!

Family Calyptræidæ.

The Slipper-limpets and their allies have the gills in long, slender plates, forming an oblique line across the cavity. They may be described as Carrier Shells, which have become tired of a jumping life, and have gone into retirement. In shape of shell, *Trochita* has a very close resemblance to *Phorus*. But instead of a leaping foot, retractile into the shell, and closed with operculum, its foot occupies the base of the "top;" and the operculum is the rock or shell to which it adheres.

In *Galerus*, we have simply a spiral plate running round inside a conical shell. In the "cup and saucer limpets," (*Crucibulum*,) the conical shell has a cup-like process within, more or less attached to the side of the saucer. In *Crepidula*, the cone is flattened into a boat, and the cup into a deck, producing the "Slipper-limpet." In all these forms, which (though differing in the types) are closely connected by intermediate shapes, the animal presents the same appearance. There is a small flat foot, and a little head, with eyes on slender tentacles, and a short muzzle with lips. The mantle scarcely extends to the edge of the shell. The tongue is armed with teeth, as ferocious as those of *Natica* and *Cassis*, and yet they seldom walk about, adapting themselves to the shape of the object to which they adhere, and growing very finely under circumstances in which locomotion is impossible. Indeed, in the genus *Calyptræa*, in which the "cup" is cut across, the animal exudes a shelly support from its foot, by which it is absolutely cemented to the rock. The remarkable changes of form which these creatures assume according to the circumstances of their growth, were detailed in the Smithsonian report for 1859, pp. 197–205. In their early stage however they are very similar; having a regular, spiral, globular shell, from the pillar of which the deck or cup is afterwards developed.

Family Capulidæ. (*Bonnet Limpets.*)

The animals in this family closely resemble the Slipper-limpets, but the adductor muscle is not fixed to any shelly support in the form of cup or deck. The shell is simply an irregular cone, twisted more or less into a spiral at the apex. Some of the living species of *Capulus* greatly resemble the *Velutinas* in form; but they are heavier shells. The *Amaltheea* eats a deep hole into the shells on which it rests, with a horseshoe ridge in the centre. *Hipponyx* deposits so thick a shelly layer under its foot (like *Calyptræa*) that the fossil species were long thought to be bivalve shells. The horseshoe muscular scar, formed by the attachment of the adductor, is very conspicuous in this family. It equally exists however in the spiral shells.

Even in the Palæozoic rocks appear forms which cannot be distinguished from the members of this family. They have been described as *Metoptoma*, *Platyceras*, *Acroculia*, &c.

Family Naricidæ.

The *Naricæ* are a group of shells, looking like cancellated *Natica*, but made by a very different animal. They are, as it were, Bonnet-limpets rolled into a true spiral shell. Their habits are sluggish, but they move about somewhat, and are provided with a very thin, sub-spiral operculum. As in the last families, the creatures are ovoviviparous, keeping their eggs under a fold in the mantle till they are ready to hatch. The shells were first called *Vanicoro* by the French naturalists, but it is scarcely fair to call a race of creatures by the proper name of a place. It is probable that the curious shells called *Neritopsis*, with a scooped out pillar lip, belong to this family. Only one species is now living, but many are found fossil in the newer rocks. Without a

knowledge of the animal, however, it is impossible to say whether its relationships are not rather with *Nerita*, or even with *Natica*. The teeth in this family are not properly known.

Family Ampullariadæ. (*Apple-Snails.*)

The Apple-Snails form a very natural and peculiar group, standing by themselves, and only presenting an external similarity to the other fresh-water shells with which they are generally associated. They inhabit the marshes of the tropical regions, both in the Old World and the New, and are particularly fine and plentiful in Africa and South America. They have a large globular shell, in some fossil species so like *Natica* that it is hard to distinguish them. In general the shell is thin, with a strong glossy skin and a horny operculum of concentric elements. Although there is no notch in the shell, the creature has almost always a long breathing pipe, like that of the Whelks; but with this difference, that it is slit along the upper not the under side.

The Apple-snails are truly amphibious, having, as it were, a gill in the corner of a lung. This arrangement is necessary to enable them to survive the long summer droughts, when they bury themselves deep in the mud and wait for better times. They have been known to live many years out of the water. Their eyes are of respectable dimensions, planted on little pillars like the Strombs, with a pair of very long, slender tentacles in front. There appears to be a second pair of shorter tentacles in front of these, but they are really the two halves of the muzzle which is split and lengthened out. The teeth are formed on the tearing type of *Natica*, &c. The creatures are eaten in vast numbers by marsh birds, who, if they cannot get at their prey through the operculum, carry them up to the branch of a tree and break the shell by the fall.

In the true *Ampullarias*, which are peculiar to tropical America, and are called "Idol-shells" by the Indians, the pipe is long and the operculum horny. The group *Pomella* have thick, heavy shells, with very wide mouth. In *Marisa*, which is found in the East Indies as well as in America, the shell is flattened down till it resembles a *Planorbis*. *Lanistes*, from the African rivers, has a flattened, reversed shell. In *Meladomus*, also an African form, the spire is turreted, looking like a reversed *Paludina*. In *Pachystoma*, which includes most of the old-world Apple-snails, the breathing pipe is short, and there is a thickened ledge round the mouth, to support a somewhat shelly operculum. In *Asolene*, which frequents the marshes of the La Plata, there is no breathing pipe visible. The estuary species are often found mixed with marine shells, both on existing shores and in the tertiary beds.

Second Group. *Teeth arranged as for vegetable food.*

Among the land snails, there are some very beautiful tribes, almost confined to the tropics and the warmer temperate regions, which cannot be properly reckoned with the true pulmonate Gasteropods. Instead of a real lung, they have (so to speak) a gill-cavity formed for air-breathing, left open by the mantle which is free from the nape of

the neck. Any one who will compare a living *Cyclostoma* with a Snail or a Periwinkle, (or their pictures,) will observe how unlike the general shape of the body is to its air-breathing ally, and how similar it is to the Sea-snail. The general resemblance is fully borne out by the details. The *Cyclostoma* has the eyes at the base of the tentacles, a long snout, a spiral operculum, and teeth arranged in seven series, 3·1·3, after the rasping fashion of the true herbivorous Rostrifers. Moreover, the sexes are distinct, exhibiting a far higher type of structure than in the hermaphrodite snails.

The *Cyclostoma* family are known, among land shells, by their graceful shape, varying however from that of a *Planorbis* to a *Turritella*, the whirls often scarcely touching, and ending in a round mouth. They are very numerous, both in sectional forms and in species. Dr. Gray divides them into thirty genera, principally on differences in the form of the operculum and mouth. The following are the principal groups.

Cyclostoma proper has a shelly, ovate operculum, of few whirls as in *Litorina*. *Tropidophora* has the whirls somewhat flattened and keeled. *Otopoma* has a ear-shaped excrescence partially covering the umbilicus. In *Tudora* (a West Indian group) the mouth is pinched at the top. *Chondropoma* has the operculum nearly horny. *Choanopoma* is a singularly beautiful group, abounding in Jamaica, with a spreading, generally frilled, lip, and a raised operculum. *Realia* is a small *Litorina*-shaped group from the islands of the Old World and the Pacific, with thin horny operculum; and *Bourciera* is a singular shell from Ecuador, shaped like *Helicina*. In this group the sole of the foot is grooved, and the animal progresses on each side alternately.

In the *Cyclophorus* group, the shell is depressed, the epidermis thick, and the operculum horny and many whirled. The tentacles are long and pointed, and the foot broad, without groove. In *Aulopoma*, the operculum has a grooved border, fitting over the lip of the shell. *Leptopoma* has the lip not complete, as in the snails. *Diplommatina* is pupiform; and *Alycœus* has the last whirl curiously distorted. So the fossil form *Ferrussina* has the mouth leaving the regular spiral, and turning upside down.

In *Craspedopoma*, the operculum has two rims, one of which fits within, the other outside the contracted mouth. *Cyclotus* has a flattened shell; and the operculum has a shelly layer outside the horny one. In *Pterocyclus*, the operculum is turretted, as in *Torinia;* and the lip is produced into a roof-shaped beak at the suture. The form is found in the East Indian Archipelago; as also *Opisthoporus*, in which a little tube comes out behind, as in *Typhis*. *Megaloma* has a cylindrical shell and horny operculum; and *Cataulus* has the base keeled round the pillar, with a horny, many-whirled operculum, which can be drawn down out like a cork-screw.

The *Pupinæ* are a group of beautiful little glossy shells from the East Indian Archipelago. The lip is notched, in front and at the suture; and the operculum is thin, horny, and many-whirled. In *Pupinella*, there is a rudimentary canal, twisted back. *Rhegostoma* has the axis bent, as in *Streptaxis;* and in *Callia* there is a shining deposit over the spire, as in the *Marginellæ*.

Family HELICINIDÆ.

This group consists of very pretty compact little shells, which most abound in tropical America, but are also found in the Pacific and East Indian islands. They have half-oval mouths, with an operculum of concentric elements. The teeth are 3·1·3, as in *Litorina*. The animal has a propensity to eat away the inner layers of its shell, like *Nerita*. *Helicina* has a plain mouth, with a lump on the pillar lip. In the West Indian group *Alcadia*, there is a slit on the basal lip, and the shelly operculum has a projecting tooth, to correspond with it. In *Trochatella*, the shell is top-shaped, and there is no lump on the pillar. In *Lucidella*, the lip is distorted with teeth. *Stoastoma* has a twisted notch, reflected as in *Pupinella*.

Family ACICULIDÆ.

A family of very small, turreted shells connects the land with the sea Periwinkles. They have the eyes on the back of the head, behind the Periwinkles, and a very thin operculum, with few whirls. *Acicula* has the outer lip of the shell plain; in *Geomelania* it is produced into a tongue.

Family TRUNCATELLIDÆ. (*Looping Snails.*)

These little creatures have a very short, round foot, and a muzzle prolonged into two lappets. They loop on these, like the geometric caterpillers. They have highly organized eyes, behind the tentacles. A peculiarity in *Truncatella* is that on reaching maturity it drops off its long, slender spire, fastening up the broken part. A little Rissoid shell, called *Tonichia*, is said to have similar peculiarities.

Family JEFFREYSIADÆ.

Among the vast group of tiny shore shells commonly called *Rissoa*, Mr. Alder found some, small among the small, who never draw their eyes outside their houses. They are placed far back behind the tentacles, and look through the transparent shells, which float among seaweeds in rocky pools. In *Jeffreysia*, the muzzle is cleft into false tentacles, as in *Ampullaria*. In *Hyala*, it is plain, and the creature has relations with *Pyramidellids*. The operculum in *Jeffreysia* is of concentric elements, with a bolt standing from it inside at right angles.

Family RISSOIDÆ.

Almost on every coast where there are any stones for sea-weed to grow from, there will be found, living among the algæ, or dead in multitudes among the sand, a great many species of shells like very tiny Periwinkles, but much prettier in their shape, sculpture, and coloring. They generally have a short, slightly cleft muzzle, joined on to the front of the foot, which is pointed behind. There is a curious little tail under the operculum. The lateral teeth are more claw-

shaped than is usual in the rasping tribes, and furnished with very minute serrations.

Already several differences have been pointed out among the animals of this tribe, which may or may not be confirmed. Some of the groups may hereafter be removed to other families. The principal genera are as follows: The true *Rissoæ* are somewhat pupiform in shape, with a thickened lip, slightly pinched at the pillar, and a thin, slightly-spiral operculum. In *Cingula*, the mouth is sharp and melanoid, with flattened whirls. *Alvania* has the whirls round and is generally sculptured; the mouth also is round, with thickened lip. In *Rissoina*, which pretty much takes the place of *Rissoa* in tropical climates, the shell is generally ridged, and the mouth thickened, produced in front, with a strong pinch at the pillar: the operculum has a tooth at the side, as in *Nerita*. *Barleia* has the shape of *Rissoa*, with an annular operculum armed with an internal stump. *Skenea* is flat like a *Planorbis*, with a round mouth and many-whirled operculum. Some forms go to the opposite extreme, and are shaped like *Turritella*. They have been supposed till lately to belong to *Aclis*. The shells of this group may always be known from the *Pyramidellids* by the point of the spire being regular, not reversed. The *Hydrobias* live in brackish water, in immense multitudes. The *Nematuras*, which float under dead leaves in the rivers of the East, are like *Hydrobia* with a curiously contracted aperture. The relations of *Amnicola* have not yet been clearly made out, though the creatures swarm in the fresh waters of North America. In shape they are intermediate between *Bithinia* and *Valvata;* but are known from both by the operculum, which is spiral, with few whirls.

Family Litorinidæ. (*Periwinkles.*)

The Periwinkles are formed for sea-shore life, and are destined to scrape off and consume the various kinds of marine vegetation. They abound everywhere except on sandy beaches, and each species has its appropriate level in relation to the tide. Some are found at extreme low water; some at the ordinary high tide; some where only the spring tides reach them; and a few where they are never covered with water except in storms. Some crawl up the mangroves on the shore, and some have been found walking on trees half a mile from the sea. The ordinary Periwinkles have one very large gill in numerous plates lying across the inner surface of the mantle. They have horny jaws, and a thin spiral operculum, generally of few whirls. In shape some of the shells resemble *Turbos*, and some *Trochuses:* but they may always be distinguished by their want of pearly lustre. The *Litorina litoria* is a favorite article of food with poor people in English cities; but the *L. rudis*, which inhabits a higher zone and brings forth its young with a hard formed shell, is left to enjoy its native rocks. The tongue is two inches long; and the creature walks first on one side of the foot, then on the other. There is a fold in the mantle presenting an approach to the breathing pipe of the Whelks. There are some river species, of Naticoid shape, which live on stones below water in the Danube and La Plata. They are called *Lithoglyphus*. The

Australian Periwinkles are top-shaped and ash-colored: they were first named *Risella*. Some species, living in marshes of brackish water both in England and the East Indies, instead of having the eyes on the base of the tentacles, as in all others of the tribe, have them on the tips; or rather perhaps on eye stalks joined to the tentacles. They are called *Assiminea*. In *Tectarius*, the shell is top-shaped, strong, and rudely knobbed outside. *Echinella* is intermediate between this form and the true Periwinkles; with knobbed exterior, often a lump on the pillar, and a many-whirled operculum. *Modulus* has also a many-whirled operculum: it is flatly top-shaped, with a deeply-cut tooth at the pillar. *Fossarus* differs from the Periwinkles in having little frontal lobes between the tentacles. The habits of the animal, as wel. as the shell, greatly resemble *Narica*. A few species from the west coast of America have a lump on the pillar, and are called *Isapis*. Shells closely allied to Periwinkles have been found in the Oolitic rocks. In the newer tertiaries, the present species are found, even with color bands; and with shells curiously distorted (as now in the Baltic) from the too large admixture of fresh water.

Family Lacunidæ.

This little tribe of northern shells differs from the Periwinkles, (which the shells greatly resemble, except that they have a chink in the pillar,) in having no jaws. Dr. Gray even assigns to them a proboscis. There are two little tails behind the operculum as in Rissoa. The *Lacuna vincta* is common in the New England seas, and deserves a careful dissection. There is no siphonal fold in the mantle.

Family Planaxidæ.

The shell of *Planaxis* differs from *Litorina* in having a sharp notch in the pillar, through which protrudes a small breathing pipe. The creatures are all tropical, and are extremely plentiful where they live. One little species is remarkable as being common both to the West Indies and the Red Sea. They have a solid, stumpy foot, and a long snout. In *Quoyia*, there is a curious sharp keel running along the pillar. The shells of this family are often remarkable for the great difference in appearance between the young and the adult state. This is peculiarly the case in the little Rissoid shells called *Alaba*, of which two extremely similar species are found in tropical America, one in each ocean. They would scarcely be distinguished when adult; but the sculpture of the nuclear snout at once separates them. The operculum is half-mooned shaped and slightly spiral.

Family Litiopidæ. (*Gulf-weed Snails.*)

The *Litiopæ* are tiny shells, very like *Planaxis*, but the animals have a curious series of lappets on each side of the mantle, as in the Top-shells. They travel over the ocean on the gulf-weed, from which they suspend themselves by spinning glutinous threads. If they lose their hold, they make a bubble which they send up to find the weed

again, having first anchored themselves to it by a thread. The operculum is said to have many whirls.

Family Valvatidæ.

Another aberrant family consists of little shells looking like fresh-water *Cyclostomas*. They have perfectly round mouths, and the shell is sometimes a little raised, sometimes quite flat. Alone of all the Prosobranchiate Gasteropods, their gills are exposed to view; being exserted, on the left side of the animal when walking, in the shape of a very slender pinnate leaf. When the animal retires, the gill is drawn into its cavity. The operculum is many-whirled. The *Valvatæ* live in rivers, lakes, and ditches in temperate regions of both the Old and New World. As the *V. tricarinata* is extremely common in the northern States, it is to be hoped that some naturalist will examine whether the creature is hermaphrodite, as stated by Dr. Gray. If so, this again is an anomaly in the Comb-gilled order. Shells not to be distinguished generically from living *Valvatas* are found even in oolitic strata, associated with *Bithiniæ*, *Paludinæ*, &c. It would appear that the types of Molluscan life have not changed in fresh waters so much as in the marine forms.

Family Paludinidæ. (*River Snails.*)

The *Paludinæ* take the place of the *Ampullariæ* in the temperate regions; but the animal is much more like the Periwinkles. They have a long, contractile muzzle; and neck-lappets, folded to make a rudimentary breathing gutter. The eyes are on stumps at the base of the tentacles. The *Paludinæ* are viviparous, the young being born with a delicate shell of three whirls. The operculum is thin, and annular as in *Ampullariæ*. The tongue-ribbon is strong but slender; the teeth not much bent, and very finely hooked. The creatures are very sluggish, generally living imbedded in soft mud at the bottom of rivers or deep ditches. They live on decaying animal and vegetable matter. The smaller species are oviparous, and have a shelly coat to the operculum. They are called *Bithinia*, and have only one neck lappet on the mantle. Among the mountain streams of Ceylon, sometimes at a height of six thousand feet, are found a group of shells remarkable among fresh-water snails for their solidity. Their surface is generally rough with knobs or ribs, and the point eroded by the acid of the water. The last whirl is very spacious, as in the *Ampullariæ*, and is closed by an operculum increasing concentrically from the margin, presenting a shape very similar to that of *Purpura*. They have been erroneously described as *Paludomus*, and are now known under the name of *Tanalia*.

Family Melaniadæ.

The *Melanias* are a tribe of fresh-water snails, abundant in all the sub-tropical regions of the globe. In America they swarm in all the southern regions, to the great delight of species-makers, who can at any time immortalize themselves by wading in some unsearched stream;

and to the corresponding confusion of those who have to work-up their achievements. They can even subsist in the severe winters of New York, but shiver at the thoughts of Lower Canada and New England. The Mediterranean appears to have limited their migration into Europe to a very few aberrant species in the extreme south. In the East Indies and Pacific islands, they again appear with something of the prolific character which culminates in the United States. They are known from the *Paludinas* by the edge of the mantle being fringed; they have no neck-lappets, but there is generally a rudimentary siphonal fold. The muzzle is large and dilated; the tongue long and slender; the gills in a series of stiff, cylindrical plates. The operculum is almost always sub-spiral, resembling *Planaxis*. The shells present considerable extremes of form; and, if marine, might be easily referred to *Mesalia*, *Fusus*, *Bullia*, *Planaxis*, *Litorina*, and *Drillia*. Yet the gradations between these extremes are so slight, and the differences in the animals of such little importance, that the separation into natural groups is a matter of great difficulty. The shells are seldom attractive, being generally covered with a dull skin, and often with adhesive mud; many of them however are elegantly sculptured, and a few have very graceful forms. It is much to be regretted that American collectors, who have not been slow to avail themselves of the exuberant riches lying at their feet, which are so acceptable to European naturalists, have so generally entirely neglected the preservation and study of the opercula; and that so many points in the physiology and habits of these easily-observed animals have not yet been made known.

The shells of *Melania* proper have a turreted spire; oval mouth, with sharp, straight lip. Like the *Paludinas*, they delight in the muddy parts of rivers, but do not despise stony places. Many of the species are said to be viviparous. In the section *Melanella*, the spire is shortened; and in *Melacantha*, there is a coronet of sharp spines. These are mostly found in the Old World and the Pacific islands. In *Melanatria*, which includes the finest East Indian forms, and many fossils of the European tertiaries, the shell is strongly sculptured; the outer lip is waved; and the operculum has several whirls, with a central nucleus. *Pachycheilus*, which includes many American forms, has a similar operculum, with a smooth shell, and a thickened pillar-lip. The stumpy, ridged *Ceriphasia* of the American rivers, and the stout, nodulous *Vibex* of West Africa, agree in having the outer lip very much waved, leaving a broad channel before and behind. *Gyrotoma*, a North American form, has a lump at the back of the pillar, and a deep, narrow slit at the suture. Very common in the whole district west of the Alleghanies are the stumpy little *Leptoxes* (of Rafinesque;* *Anculotus* of Say); which are like fresh-water Periwinkles in their habits. Having no tide-waves to dash them, they establish themselves on stones in the rapid places of rivers in such numbers that

*The description is so inaccurate that Philippi in his Manual assigns it a place among the Lymneids. The name of Say was in common use till the conchological archæologists revived the prior but deservedly forgotten name of Rafinesque. Changes of currency, however necessary to introduce the benefits of a decimal coinage, are not necessarily useful to science, merely because a bad coin was made before a good one, which has got into general acceptation.

often you cannot tread without crushing them. They live a sedentary life, adhering pretty firmly to the surface by their short, strong foot. The spiral part of the operculum is often worn away. They are represented in the Himalayan regions by *Paludomus;* which, with the fringed mantle of *Melania*, has the annular operculum of *Paludina*. In the West Indian islands and the tropical districts of South America are found a group of shells differing from the typical *Melanias* in having the pillar sharply notched; they are called *Hemisinus*. The genus *Melanopsis*, which is peculiar to the old world, being found from Spain to New Zealand, consists of stumpy shells notched for the siphonal fold, and furnished with a lump at the suture like *Bullia* and *Polinices*. The elongated forms, found in Africa and the tropical East Indian islands, are called *Pirena*, and have the lip very much produced in front. The shell of *Clionella* has a distinct notch in the outer lip like *Drillia*. It inhabits the African rivers, but the animal has not yet been examined. Lastly, in the Southern States of America are found the beautiful shells of *Io*, in which there is not merely a notch, but a distinct, straight canal, to convey water to the gill cavity.

Family Cerithiadæ. (*Cerites.*)

The Cerites are a very numerous tribe of turreted shells, with a notch or canal at the bottom of the pillar, in consequence of which they were classed with the *Muricids* by Lamarck. The animals however closely resemble the Periwinkles, *Melanias*, &c. They are known from the latter by the absence of fringe on the mantle, by their strongly sculptured shells, and by the greater development of the siphonal fold in the mantle. This is never produced into a projecting recurved pipe, as in the notched Proboscidifers. The Cerites are found in all parts of the world; but the typical species do not ascend higher than the Mediterranean. Some of the species emit a bright green fluid when disturbed. Like their neighbors the Periwinkles, they are extremely plentiful in individuals. They inhabit the ebb-tide line and deeper waters round shores, and certain groups are very plentiful in brackish water and salt marshes. The shells of *Cerithium* have a very short, slightly bent canal, and an operculum like *Litorina*, of few whirls. *Rhinoclavis* has the canal bent back like *Cassidaria*, with a fold on the pillar, and a porcellanous texture in the shell. The fossil group *Nerinœa*, found in the older secondary rocks, is like an exaggerated *Rhinoclavis*, with a large number of plaits, both on the pillar and inside the whirls. The shell is often very slender like *Terebra*, which it may have resembled in habits. One species of *Rhinoclavis* has been figured by Adams with a muricoid operculum, but other species are known to possess the paucispiral form. In the remaining members of the family, the operculum is round, with many whirls. The dwarf Cerites of the northern seas have only a slight pillar notch, and bear some resemblance to the elongated *Rissoas;* they are called *Bittium*.

The fresh water *Potamides* are known by their brown epidermis, and lip produced in front. The fossil forms are very numerous and beautiful in the tertiary strata. In *Pyrazus* the outer lip is arched

and twisted over the canal, making it somewhat tubular. *Lampania* has a shell shaped like *Pirena*. *Terebralia* has a broad pyramidal shell with flattened whirls. The mouth is square, with a deeply waved outer lip, and a plait on the twisted pillar. The *T. telescopium* is so plentiful near Calcutta as to be burnt for lime. In the very pretty group *Cerithidea,* the notch is almost obsolete; the mouth is round; and on reaching maturity it is reflected back. The shells are very thin and light, and very commonly decollated at the point. The animals live in mangrove swamps, estuaries, and salt marshes. They crawl so much out of the water that they have been taken for land shells; and in the dry season, they hang themselves from the mangroves by glutinous threads.

It is not known whether the animals of *Triforis* are most related to *Cerithium* or *Cerithiopsis*. Perhaps among the lefthanded species which have been grouped together under that name, there may be found some of each kind. (See *Cerithiopsidæ*, above, page 185.) The ancient Cerites are of the *Nerinœa* form: the typical race does not appear till the cretaceous age, but rapidly develop in the tertiaries.

Family Turritellidæ. (*Screw-Shells.*)

The *Screws* are to the vegetarian section of Comb-gilled Crawlers, what the *Augers* are to the boring tribe. The shell is very long, and regularly pointed; the whirls very numerous and generally rounded; and the texture for the most part strong, and somewhat porcellanous. The creatures do not drop away the pointed end, like *Cerithidea* and *Truncatella;* but they are fond of marking off the left portions, one after another, by plain partitions. In external appearance the Screw-mollusks are extremely like the *Melanias* and *Cerites*. They have a very short foot, squared in front; and a short, thick muzzle, somewhat united to the foot below. The mantle is fringed even more prettily than in *Melania*. The operculum is round, with many whirls, as in *Potamis;* often with a thin fringe at the edge. As the foot is grooved below, the creature has the power of moving right and left alternately. But the heavy, long spire and short foot betokens in general a sluggish habit; and the Screws generally repose in stiff mud like the Augurs, in rather deep water. But while the blind Augurs grub *in* the mud for their prey, the Screws expose their delicate fringe and long thin tentacles with eyes on stumps beneath to search for their food above the surface. The teeth are broad and extremely finely serrulated, like those of *Paludina;* the tongue-ribbon being very small. There is a rudimentary breathing fold, but the pillar is not notched. The gill-comb is extremely long.

The animals have not been examined in a sufficiently large number of species to ascertain whether there are any generic differences among them. They have been thus separated provisionally, according to the shell. *Turritella* has the mouth round. In *Haustator*, it is somewhat squared by the shouldering of the base: very fine species of this group are found in west tropical America. In *Torcula*, the middle of each whirl is curiously hollowed out. The shells of *Mesalia* are short, with flat-

tened whirls, oblong mouths, and waved outer lip. They are like strong marine *Melanias*, and are found in Greenland, Africa, and the Eocene tertiaries. *Eglisia* has a deeply-marked suture, small mouth, and thickened pillar. Shells apparently belonging to this family are found in very old rocks. The typical forms begin in the neocomian strata, and are exceedingly abundant in the tertiaries. Among the latter is the genus *Proto*, in which there is a broad notch near the front of the pillar. The shells of *Scoliostoma*, which range from the Devonian to the Trias, form a remarkable transition to the Vermetids, the aperture being produced and trumpet-shaped.

It is difficult to say what are the true relations of the

Family Cæcidæ,

whose tiny shells, like bent tusks, closed at one end, are seldom seen in the cabinets of collectors, but present many points of singular interest to the inquirer. The *Cæcum* is first born as a flat spiral shell, like *Skenea* with which indeed the animal has not a few relations. But after making two or three turns, it suddenly leaves the spire, and grows outwards in a very slightly arched curve. In this state it remains permanently in *Strebloceras*, the earliest Cæcids known, from the London Clay; like a shepherd's crook, twisted at one end into a spiral. But in the living genera, it soon drops off the spire, plugging up the broken end; and as it advances in growth, it brings the plug forward, and drops off the part behind, always living in a part about the same length, broader in proportion as it approaches maturity. In *Cæcum* proper, the shell advances in the same plane; so that if all the decollated parts had been preserved, the whole would have had somewhat the shape of a *Spirula*. In the West Indian genus *Meioceras* however, where the shell has to keep pace with the growth of the sponge among which it lives, the coil is in loose cork-screw, like a drawn-out *Turritella*. The animal agrees with *Turritella* in having a short foot and many-whirled operculum: also in partitioning off its forsaken portions. But the division, instead of being a homogeneous septum, continually repeated, as in the Screws, is a very curiously-shaped plug, the form of which is constant in each species. The teeth, instead of being broad, with fine serrations, as in the Screws, are said to be pointed and hooked, as in the carrion-feeders. As they are principally found in worm-eaten passages of dead shells, they may be employed as scavengers, to scrape up the decaying matter that might otherwise corrupt the water. The adult shell has both its mouth and plug slanting, so that it may be able to crawl through a very narrow hole. In the earlier stages, the shells of all the *Cæca* are smooth and slender; but as they attain maturity, the group *Anellum* develops concentric rings, the *Elephantulum* longitudinal furrows; while the shells of *Fartulum* are smooth, and look like tiny sausages. In *Brochina*, the plug is spherical, and the operculum swelling outwards. The Cæcids culminate in tropical America, east and west; and are curiously rare in the Pacific ocean.

Family VERMETIDÆ. (*Worm-Shells.*)

On almost all shells and stones that have lain long in the sea are to be found irregularly twisted shells, sometimes assuming a more or less spiral form, sometimes almost straight. A large proportion of these have no connection with shell-fish: being true worms, the sea analogues of the earthy tribes; jointed animals with red blood and symmetrical organs. When taken alive, these are recognized by the beautiful bunch of feelers, bearing an operculum (sometimes adorned with stag's horn processes, and never spiral) on a fleshy cup in the middle. Some of these, as the tiny *Spirorbis*, so prolific on sea weeds, stones, &c., in the colder seas, have pretty regularly formed spiral shells. But in the tropical and warmer temperate regions, many species are found, the animal of which is not indeed so beautiful, but far more highly organized. It is indeed a true mollusk, and may be considered a degraded *Turritella*, adapted to a fixed life; just as *Magilus* is a degraded *Purpura*.

In *Vermetus* proper, the shell begins exactly like a ridged *Turritella*. The animal is of course then free, and will probably be found to have its foot somewhat developed. But after a season, tiring of its too great exertions, it lies down in a safe place, attaches itself to the mooring, and continues its shell in an irregular twist. The foot then becomes obsolete, or rather serves the purpose of a support for the operculum. The head has short tentacles with little eyes; and a small muzzle, often cleft into false tentacles, as in *Ampullaria*, *Rissoella*, and the *Slipper Limpets*. The teeth have not yet been examined. The gill is very long and slender; and the mantle edge is sometimes fringed.

The shells of *Siphonium*, though spiral at birth, have no *Turritelloid* portion. The operculum is thin and concave, with very few whirls: in *Aletes*, it is many-whirled, as in the Screw-shells, but small in proportion. In *Bivonia*, the operculum is shaped like a "wide-awake" hat, so as to be drawn very tightly into the shell: the outside is terraced, and often encrusted. In *Petaloconchus*, the operculum is very thin, and the middle whirls of the loose spire very curiously cut up by thin spiral laminæ, reminding one of *Nerinœa*, or of a drawn out Calyptræid. These two last groups are often twisted together in large masses, stretching out straight tubes at the end to get the best access to the currents. The shell of *Spiroglyphus* is partly imbedded in the living shells to which it adheres, growing in the form of *Spirorbis*. In *Serpulorbis* and *Cladopoda*, there is no operculum, the foot of the latter being produced like a club. The shells of *Siliquaria* have either a slit or a necklace of holes, running along the whole outer edge of the irregular spire; corresponding with a slit in the mantle to admit water to the long gills. The operculum is terraced as in *Torinia*. The animal is said to be hermaphrodite; another mark of inferior development connecting this with the next order.

The shells of this family cannot be certainly distinguished from those of sea worms; but can in general be recognized by their compact porcellanous texture, glossy within, like an unrolled *Turritella:* while the worms are generally of dead hue, and earthenware consistency.

We have now completed our sketch of the Comb-gilled Crawlers; the largest, and (except the Cuttles) the most highly organized group of mollusks. In the next order, the gills consist of two series of plates, more like those of the bivalves. This comparatively trifling distinction is found to be coördinate with an inferior type of development in other points of structure. The animals, while often much more ornamented than in the former order, are not as it were so concentrated. There is never found a breathing pipe or a predacious snout. The teeth, instead of being compacted into rows of 3·1·3, each one of which has its special shape, are spread out into very complex series of glassy hooks, of which many in the same line are the dittos of each other. The shells, while many of them are of surpassing beauty, nacreous as the pearl oyster, often lose their spiral form, adopting that of the simple cone. And the arrangements for the continuance of the species, instead of being separated on different animals, are united in the same individual, which is supposed to be capable of self-impregnation.

Order SCUTIBRANCHIATA. (*Shield-gilled Crawlers.*)

Family Neritidæ. (*Nerites.*)

Almost all the Scutibranchs are shore shells, living wherever there are rocks or marine vegetation. Some are found at slight depths; a few of the lower kinds only being found in deep water.

The Nerites are almost exclusively confined to tropical shores. They grub among the stones and rocks on the sea-weed, sleeping by day, and prowling about, harmless as they are, towards night. They are plain-looking creatures, like the Periwinkles, from which they are at once distinguished by the great length of their tentacles, and the eyes which rise on short stumps behind. The shells are very readily distinguished by the broad flat pillar-lip and stumpy spire. Though greatly abounding in species and in individuals, there are very few generic forms among them. The true *Neritas* are strong, sea shells, with stout teeth or wrinkles on the pillar lip. The operculum is subspiral and shelly, with a stout knob fitting like a hinge under the pillar lip. The *Neritinas* are much thinner shells, almost exclusively inhabiting fresh waters, where they adhere to stones or water plants. The pillar lip is thin and smooth, or only very finely toothed; the operculum also is thin, with a horny edge. In the group *Clithon*, the whirls have a row of spines pointed towards the apex. These live on stony bottoms, in still, tropical waters. Some of the *Neritinas*, especially in the group *Neripteron*, with winged pillar lip, have very short spires; they then pass into the fossil form *Velates*, which is peculiar to the French tertiaries. Here, while the mouth of the shell has the usual Neritoid appearance, the back is conical, with only a minute spire at the point. In *Pileolus*, a form peculiar to the oolitic rocks, there is no spire at all, the back of the shell being exactly like a limpet. Another oolitic form, *Neritoma*, has a notch in the outer lip, like *Pleurotomaria*. A large group of fresh-water Nerites in the East Indian Archipelago are limpet shaped, but with the point at the side,

resembling a fresh-water *Crepidula* with an operculum. These are the *Navicellas*, the operculum being small, and imbedded in the foot. *Pelex* is a little New Zealand shell, brought home by the United States Exploring Expedition, in which the apex is on one side.

All the Nerites have the power of absorbing the inner whirls of the shell, which makes the transition from the spiral to the straight forms less extraordinary. The teeth are arranged in very complicated patterns, the inner rows being of many different shapes, flanked by numerous rows of hooks at the sides.

The great bulk of the Scutibranchs consist of the Top-shells, forming the staple of Linnæus' two genera *Trochus* and *Turbo*. The animals are all formed on the same type; and are known by the beautiful fringe and feelers round the foot and head, the long tentacles and eyes behind on stumps, and the long and very complicated tongue-ribbon. Although the animals can be easily obtained and examined, being very generally found between tide-marks, the beauty of the shells has generally engrossed the attention of collectors; and we are left in ignorance how far the observed differences in these are coördinate with distinctions in the living creatures. The divisions, both into families and genera, are therefore for the most part artificial; but are rendered necessary in consequence of the great multitude of species. They are found in all seas, from the tropics to the frozen ocean. When their beautifully sculptured and delicately painted shells are found in company with the dull Periwinkles, and their highly ornamented bodies are compared with the plain forms of the latter, it is difficult to realize the fact of their greatly inferior organization.

Family Turbinidæ.

The shells of this group are all tropical, or nearly so. They reach the Mediterranean, but not the British or temperate American seas. They are distinguished by a very thick shelly operculum of few whirls. The under layer of the shell is brilliantly pearly.

The *Turbo* group have rounded whirls and a circular mouth. The large species are imported in great quantities to be polished for ornaments; the hemispherical opercula used formerly to be regarded as a charm for sore eyes. The typical species have a smooth, or slightly granular operculum. In *T. sarmaticus*, the surface is made up of large granules. The Snake-shell group, which abound in the Pacific islands, have a very rough outside, and a chink at the pillar. The shells of *Marmorostoma* are flattened, with a deep umbilicus, and a groove round the operculum which has more whirls than usual. *Ninella* is broad and thin, with a wide, channeled umbilicus; the operculum is nearly flat, with ridges like the human ear. The shells of *Callopoma* are like the typical forms; but the opercula are deeply grooved, with beautiful granular ridges. They are peculiar to west tropical America. To the south of *Callopoma*, on the west of South America, is found *Prisogaster*, with the shape and dull aspect of *Litorina*, but a shelly, sharp-edged operculum of few whirls. The New Zealand form *Modelia* has the general shape of *Ziziphinus*, (a species of which is unfortunately figured in this place in Chénu's Manual, f.

2551,) but it has a stony operculum, with two grooves outside. The pretty little African group *Collonia*, have small Trochoid shells, and a many-whirled shelly operculum with a central pit. Species belonging to this type are found in the Paris Eocene beds. Fossils of Turbinoid form, which may or may not belong to this family, are found in all ages from the earliest times.

Another group, typified by *Imperator*, has the shell top-shaped. The whirls and base are flat; the operculum thinner and oblong. The shell is always roughly sculptured, and often considerably incrusted. The large *Pomaulax* of Lower California has a channeled base, and an operculum with three bent ridges. *Uvanilla* has a similar base, with two ridges on the operculum. The New Zealand *Cookia* has one ridge, and a shell shaped like *Modelia*. The shells of *Astralium* have a very flattened spire, with a sharp keel round the base armed with spiny scales. An aberrant form of this is the Japanese *Guilfordia*, which has a brilliant, golden nacreous texture, and a few long spines.

Family Phasianellidæ. (*Pheasant-Snails.*)

The shells of this group differ from the *Turbos* in being porcellanous, but not nacreous. The shelly operculum is smooth outside. The shells are always smooth, and very brilliantly painted. They have much the shape of Periwinkles, and the animal has a very long snout. Small species are found in most warm seas, but their favorite haunt is Australia. This part of the world retains the oldest fauna now living, and has many points of similarity with that of the oolitic rocks. The prevalence of large *Phasianellas* in the European oolites and present Australian seas is a striking case of similarity.

Family Trochidæ. (*Top-Shells.*)

The animals of this family are very beautifully fringed, and the shells generally highly painted. Very few excel them in the elegance of the sculpture, and the beautiful shapes of their pearly mouths. The shells are generally thinner than the *Turbos*, from which they may always be known by the thin, horny, glossy operculum of many whirls. The genera into which the old genus *Trochus* have been lately divided, cannot be regarded as established until the peculiarities in teeth, fringes, opercula, &c., have been examined in a much larger number of species. The following are the principal groups: The typical species are conical, with many whirls, the last of which often bulges, with the pillar-lip twisted and concave in front. In *Cardinalia*, the surface is sculptured, the last whirl a little narrowed-in, with the pillar-lip ending in a point in front. The small conical shells with a flat pillar and square mouth, which for number and beauty might be considered the principal of the groups, have been called *Ziziphinus*, from the commonest European species; but as great confusion arises from raising specific names to the generic peerage, it would be far better to revive Swainson's name *Calliostoma*. In *Pyramidea*, the whirls are very angular and narrow, and the pillar is sharply twisted so as to approach *Terebralia* among the Cerites. *Polydonta* has the bottom

of the pillar scooped out, and the lip ornamented with blunt teeth. When these become obsolete, with sharply keeled whirls, the shell resembles *Trochita* among the Slipper-limpets, and is called *Infundibulum*.

The Australian and New Zealand Top-shells present some curiously drawn-out forms; in which the nacre has generally a greenish hue. The shell of *Cantharis* has a plain pillar, like *Phasianella*. In *Elenchus*, which is polished and painted like the Pheasant-snails, there is a tooth on the pillar; and in *Thalotia* the mouth is toothed round. *Bankivia* is a curious *Eulima*-shaped shell, with the pillar bent and truncated. Although it is so common as to be used for ornaments by the natives, its operculum and animal are still unknown.

In the next group the shape of the shell is more ovate, with flattened spire and rounded base. *Livona* has convex whirls and a round mouth, with a deeply-pierced pillar and lump bordering the hole. The *L. pica* is one of the most characteristic shells of the West Indies: a closely allied form was taken alive by Colonel Jewett in California. The operculum has fewer whirls than is usual in the tribe. *Trochiscus*, a form peculiar to California, is nearly allied, but has the operculum with raised and scaly edges. In *Gibbula*, a very common European form, the whirls are shouldered, and the pillar-lip is plain. *Margarita* is a closely allied boreal group, with very thin shells and round mouth. The very similar forms *Oxystele* and *Diloma* are like a *Livona* with a closed pillar.

The shells of *Clanculus* are remarkable for their ringent mouths, twisted by numerous teeth. *Monodonta* is shaped like a Periwinkle, with one stout tooth on the pillar, and others round. *Euchelus* differs from it in being umbilicated, with but few whirls in the operculum. *Osilinus* is like Monodonta, with only one plain knob on the pillar. *Omphalius*, the shells of which replace *Gibbula* on the west coast of America, is like a plain *Clanculus*, with the pillar lip toothed, somewhat as in *Modulus*. *Tegula*, which is peculiar to the Panama region, has the mouth of *Osilinus*, with the Trochoid shape of *Omphalius*.

Monilea is a little group of sculptured shells, resembling *Torinia*, in which the open pillar is bounded by an ornamented spiral ridge.

The *Delphinula* group are in shape like strong, shaggy sea *Cyclostomas*. The pillar is quite open; the whirls scarcely touch; and the mouth is round.

Several fossil forms appear allied to this and other recent genera; but in ignorance of their opercula, we cannot locate them with certainty. *Euomphalus* is like a flat, thin, unsculptured *Delphinula*, with angular mouth. The typical species of *Cirrus* are so irregular that they might be considered *Vermetids*. The *C. nodosus* of the English Oolites, sometimes begins as a left-handed *Turritella*, ending in a flat *Euomphalus;* and sometimes take a reversed top-shape from the beginning. In some species, the whirls are disunited. Some species of *Euomphalus* are believed to have had a stony operculum like *Turbo*.

Family Liotidæ.

Some of the shells classed with *Delphinula* are found to have the

horny operculum ornamented outside with spiral dottings of shelly matter. The mouth always ends in a round varix. They are separated under the name *Liotia*.

There is a group of very beautiful little white shells, with flattened spire and large mouth, the relations of which are not yet properly ascertained. As far as the shells are concerned, they pass both into *Liotia* and *Rotella* by insensible gradations. The shells are not pearly as in the Trochids. The species are very numerous in west tropical America, and probably in other warm seas, but have hitherto escaped observation. They are here provisionally classed with *Rotella* simply from the relations of the shell.

Family Rotellidæ.

The shell of *Rotella* is like a marine *Helicina*, flattened, with a large lump on the pillar. It is glossy, but not pearly. The operculum is horny and many-whirled. The animal is said to have a retractile proboscis. At any rate it offers the anomaly of having only one of the eyes properly developed. One of the tentacles is curiously transformed into a long veil, which has been mistaken for a breathing pipe. The creature is said to grub in sand, like the *Naticas*. The shells are beautifully painted, with such variety of pattern that it is hard to find two alike. Several allied forms are found in the secondary rocks. *Chrysostoma* takes the form of the Periwinkles, with a very small lump. *Camitia* is toothed, like a polished *Clanculus*. *Isanda* has an open pillar, with a toothed mouth. *Teinostoma* is like a *Rotella*, with the mouth drawn away from the pillar, and often ending in a pinch. *Ethalia* is intermediate between the three last forms; having an open pillar nearly covered by the revolving lump of the inner lip. In *Vitrinella* there is no lump; the pillar is extremely wide and open; and the outer lip is often waved. The shells are all minute; and are remarkable for the large size of the nucleus and the beauty of the sculpture. *Cyclostrema* is like a large *Vitrinella*, with a round mouth; it is said to have a shelly operculum. Lastly, *Adeorbis* has a very open mouth, with the outer lip doubly waved. In form, this group passes into the next family.

Family Stomatidæ.

These may be described as Ear-shells without any holes. The animals are like those of *Haliotis*, but without the mantle-slit. Like them the mantle is fringed, but there are no feelers round, as in the Trochids. They pass into the former family though the genus *Stomatella*, in which the shell is shaped like *Sigaretus*, and the animal can be drawn into it. There is a small, horny operculum of few whirls. The shells in the whole family are brilliantly pearly; they are small, and almost confined to the East Indian islands. In *Stomatia*, and the remaining genera of the family, there is no operculum, and the animal cannot withdraw its large foot into its shell. Sometimes, when frightened or angry, it throws off the back of the foot, like the Harps. In *Microtis*, which has a flat, spiral shell exactly like an unbored *Haliotis*, the foot is cleft in front below the head. In *Gena*, the shell is drawn out, and

the spire very small. Just as we found conical forms among the Nerites, so we have a conical Trochid. It is called *Broderipia*, and looks just like a small, pearly Limpet.

Family PROSERPINIDÆ.

A curious little family of land shells are believed by Dr. Gray to have the same relations to *Nerita* and *Trochus* that *Cyclostoma* and *Helicina* have to the Periwinkles. They differ from the true Pulmonates in having the mantle free from the nape, leaving the breathing cavity open. They differ from *Helicina*, &c., in having glassy teeth in complex pattern like *Trochus*, and in having no operculum; in which respect they resemble *Stomatia*. The mantle is unadorned, as in *Nerita;* and, like it, has the power of absorbing the inner whirls of the shell. On the other hand, it is said to be unisexual, in which it resembles the Pectinibranchs rather than the present order. The group is West Indian, and contains two genera: *Proserpina*, in which the whole shell is glossy, like *Pupina;* and *Ceres*, in which it is keeled, and only the lower region is polished. In both there is a lump on the pillar, as in *Rotella;* and there are spiral ridges inside the mouth.

Family SCISSURELLIDÆ. (*Slit-Top Shells.*)

Till lately it was believed that there was no living representative of the vast tribe of palæozoic and secondary *Pleurotomarias;* except the tiny little shells of *Scissurella*, which resemble a *Vitrinella* with a slit in the mouth, or a spirally curled *Emarginula*. The tiny animal has been examined, and found greatly to resemble *Cyclostrema*, having very highly developed pinnate feelers at the sides. In some species the slit of the young shell is afterwards closed into a hole; in others, the hole is seen in the earliest stage, and is moved on as in *Rimula*.

But the true *Pleurotomaria*, which was believed to have passed away before the Tertiary age, is now known to be living, a beautiful specimen having been dredged in deep water near the island of Marie Galante, so like the Oolitic forms that it might, if fossilized, have passed for one of their race. It is exactly like a pearly *Calliostoma*, with a slit lip. More than four hundred fossil species are known, some of them as large and solid as the *Turbos*, some as inflated and thin as *Scissurella*. In form they vary from *Elenchus* to *Euomphalus*, and are either keeled or rounded at the base. In *Trochotoma* there is a hole behind the lip, instead of a slit. In *Polytremaria* there is a row of holes in a spiral necklace, as in *Siliquaria*. The shells of the palæozoic group *Murchisonia* are elevated like a *Melania;* while those of *Schizostoma* are depressed like a *Euomphalus*, with a doubly waved lip like *Terebralia*. Another palæozoic form, *Catantostoma*, has the last whirl twisted downwards. The closely allied shells of *Scalites* and *Raphistoma* are very thin and depressed, with the whirls keeled and the outer lip pinched but not slit.

?? *Family* MACLUREADÆ.

Of several other palæozoic forms, even the family position is as yet doubtful. One of the most singular is *Maclurea*, a Euomphaloid shell

characteristic of the Chazy limestone, in which the solid operculum has an upright support, as in *Jeffreysia*. It is supposed by some to be related to *Bellerophon*. It is very difficult to determine the relations even of recent shells, when the animal has not been seen, because the shells of such different mollusks are very like each other. Much less can we expect to understand the relations of abnormal fossils, when even the texture affords no clue, and the peculiarities of the mouth can be so seldom examined.

Family HALIOTIDÆ. (*Sea-ears* or *Ormers*.)

The very beautiful group of ear-shells may be regarded as *Turbos* flattened out to adhere to rocks. They present however several characteristic differences of structure. There are two gills and two auricles, instead of one as in the Top-shells; and the foot is greatly dilated and very strong. They adhere so tightly to the rocks that they are often forced off by the point of the bayonet. The best way to loosen them is to pour warm water on, and then jirk them with the foot. They are often cooked; and the shells, which present a very brilliant nacre, golden, green, orange, pink, &c., according to the species, form a regular article of trade for ornaments and inlaid work. The muscular attachment, instead of being horseshoe-shaped, as in ordinary univalves, is round and central as in the oyster. There is always a ridge along the back, with a few holes near the edge. These are filled up as new ones are made. Below them is a slit in the mantle to correspond. The foot is very elegantly fringed, and the teeth are complicated as in the Top-shells. The *Haliotis* tribe are rare in the tropics; but abound in Japan, California, and Australia, and are found along the east coast of the Atlantic. Their absence from the whole of the South and tropical America and the eastern shores of North America, is very remarkable, seeing that they abound from Kamtschatka to Cape St. Lucas. The shells of *Padollus* have a second spiral rib, but without perforations. In *Teinotis*, (the *Ass's Ears*,) the shell is thin and glossy; the animal being very active, with a large foot. It is thought that the number of holes is constant in each species; but this is very far from being the case. In the Californian species, they vary from two to four, and from five to ten.

Family FISSURELLIDÆ. (*Key-hole Limpets*.)

In this large and beautiful family the body is symmetrical, and only spiral in the first stage. There are two gills at the back of the neck, one on each side of the shell, the vent being between them. This discharges, in the sea-ears, into the last hole: in this family into a hole or slit which is variously situated in the different genera. The foot is large and more or less fringed, as in the preceding families; but the shell is not pearly, and there are no eye-stumps. As in all other Limpets, (with which however they have not a very close connection,) the muscle is horseshoe-shaped. The teeth are arranged in complex patterns, as in the preceding groups. They are found on all shores, though sparingly. The largest species are from South America.

The shell of *Rimula* is nearly related to *Scissurella*, but is formed in

a flat spiral, with a rapidly enlarging mouth. The hole is behind the outer lip, as in *Trochotoma*, and is gradually brought forward, the part behind being filled up. The animal must therefore have the power of eating out its anal orifice, as it grows older. The shells are found fossil in the oolites, living in the East Indian archipelago, and in the Gulf of California. The boreal form *Puncturella* resembles it, but with a plate inside to support the anal siphon which is rather long. The young shell of *Glyphis* exactly resembles *Rimula;* but as the animal grows, it becomes conical; and instead of moving the hole, it enlarges it where first formed, till at last the whole of the spire is eaten away. The animal is larger than the shell, which is always prettily cancellated, and crenulated at the edge. In *Fissurella* proper, the spiral nucleus has not been detected, even in very young shells. The animal can be entirely drawn into the shell. In most species, the shape is very constant; but in some, there is great irregularity, not only in the form of sculpture, but even in the shape of the hole. A curious specimen from Mazatlan has two holes; and another still more extraordinary one, found in Chili by D'Orbigny, has none. *Clypidella* has a singular, flat, waved shell, with a narrow key-hole. *Macroschisma* has a slug-shaped body, projecting in front of the shell; which is oblong, with a very large hole behind. The great *Lucapina* of the Californian coast has an animal as large as a dinner plate, almost covering a flattened crenulated shell. *Fissurellidæa,* from the Cape of Good Hope and Tasmania, has a very similar animal and shell, but with a smooth border. The shell of the African *Pupillæa*; also covered by the mantle of the animal, has a sharp, smooth edge.

Another group have the anal orifice in front. *Emarginula* has a shell like *Rimula*, but with a slit in the outer lip like *Pleurotemaria*. The shells are always sculptured, and are from deep water. Fossil species first appear in the Trias. In the group *Hemitoma*, the slit is very small; and in *Clypidina*, it is simply a wave. In the "Duck-bill Limpets," *Parmaphorus*, the shell is white, and almost covered by the black mantle, under which is an enormous foot: there is only a broad wave for the excretory passage.

In the remaining families of the Scutibranchs, no tendency has been observed to spiral developments, even in the young shell. There are no fringes to the mantle margin; and the animal is generally of sluggish habits, and covered entirely by the shell. The teeth also are formed on a much simpler plan, consisting of a few longitudinal series, of variable form.

Family Gadiniadæ.

A small family of shells, from the west coasts of the Old and New World, have characters in common with the *Siphonariæ*, or air-breathing Limpets. A groove is seen within, proceeding from apex to margin on the right side, going over the muscular scar. This is probably for the vent, as in the last family. But there is only one gill, placed sideways across the back of the neck; and the tentacles are funnel-shaped. None of the species are colored. They often adhere to other shells, eating out cavities like the Cap-limpets. The west American

form, described as *Gadinia pente-goniostoma* has been found with six, five, four, three, two, corners, or only one; or quite round, which is its normal state. So much may we err by describing from single specimens.

Family ACMÆIDÆ. (*False Limpets.*)

The shells of all the Limpets are so like each other that no characters have yet been found to distinguished them generically. But the accurate Russian naturalist Eschscholtz, when examining the Limpets of the Californian coast, found that they differed materially from the true Limpets in the shape of the gill. While the ordinary Rock-limpets have the gill greatly developed, going all round the margin of the shell, as in the oysters, these deeper water species have one small gill on the left side of the neck, like the Top-shells. The teeth also are in rows of not more than six each. It would have been very convenient if these very different gills had left their different marks inside the shells; but all the fancied marks turn out fallacious; the animals of reputed *Acmœas* turning out to be Limpets, and *vice versa*. Further, among the single-gilled Limpets, there are now found considerable differences; the large *Tecturina grandis* of the Californian coast being the type of a separate group. The white, conical *Scurria mitra*, which makes holes for itself in the roots of sea weeds in the west temperate regions of both North and South America, (avoiding the intermediate tropical region,) has a fringed mantle, looking like a gill, all round the inner edge of the shell. The shells of the beautiful group *Scutellina* are thin, finely sculptured, and very glossy inside. They often have a rudimentary pillar lip, like *Navicella*, which caused the west American species to be described by Prof. C. B. Adams as a *Crepidula*. The little Scotch *Pilidium* has a somewhat similar shell. The animal of the boreal *Lepeta* is blind; its teeth are curiously ornamented like a stag's head.

Family PATELLIDÆ. (*True Limpets.*)

The largest known Limpet (*Patella mexicana*) inhabits the rocks of west tropical America, growing to be a foot across, and of capacity large enough for a French lady's wash hand basin; else, this tribe, so abundant elsewhere, is remarkably absent from North America. The rocky shores of the Old World are covered with them, almost always above the region of the Acmæids; sometimes at such high levels that they can rarely be dashed over with sea water or find anything to eat. Like the Ear-shells, they adhere very firmly to the rocks when once touched, by means of their strong muscular foot, grooved across the middle. The tongue of the common English Limpet is longer than the shell itself; containing 160 rows of twelve teeth each, or 1,920 little glassy hooks. With these it rasps the nullipore and sea-weed, principally in the night. It has the organs both of adhesiveness and inhabitiveness large, growing according to the shape of the rock which it selected, and where it always returns to roost. In one county of Scotland twelve millions have been collected in a year for bait; and near Larme, in Ireland, many tons' weight are annually collected for

food. The gill goes round both head and body, just under the shell; and is ornamented with very beautiful fringes, sometimes of two hundred filaments. One of the south African Limpets, *Olana*, has a snout in front of the shell; but whether the animal has any coördinate peculiarity, has not been ascertained. The shells which Messrs. Adams call *Cymbula* are believed to be only True Limpets altered into a compressed form to living on stems of plants. The *Nacellæ*, or horny, Sea-weed Limpets, alter in form in the same way. They have the gill interrupted over the head, forming a transition to the Acmæids. The shells of the African *Helcion* are like an *Emarginula* without slit.

Fossil Limpets are found in rocks of all ages; but of course their generic position is uncertain. The Limpets, more perhaps than any other shells, require to be studied geographically, with careful dissections of the animals, and with diligent comparison of a large multitude of specimens.

The last family of this order presents special characters so different from any other mollusks, that if they alone were attended to, it would be necessary to form a class for their sole occupation. Nevertheless, they have so much in common with the Limpets that they are generally included in this order.

Family CHITONIDÆ. (*Coat-of-Mail shells*, or *Sea-woodlice*.)

It has been well said that the *Chitons* have their backs armed, like the Isopod Crustaceans; their gills, like those of the Brachyurous Crustaceans; their heart, in a long vessel down the back like a Sea-worm; their reproductive organs symmetrical and repeated on each side, like the bivalves; a crawling foot and head, like a Limpet; a posterior vent, like the *Fissurellas;* and a leathery skin, like the Tunicaries. According to the old-fashioned division of shells into univalves, bivalves, and multivalves, they were driven by Linnæus to keep company with the headless *Pholas* and the Crustacean *Lepas*. For they have eight distinct shelly plates, fitting over each other like tiles, the middle ones marked off in sculpture by diagonal lines, and all of them let into the tough mantle by sharp smooth edges, like *Pupillea*. Outside, the creatures have a general resemblance to the bodies of Trilobites; and, like those strange denizens of the palæozoic seas, or the living Woodlice, they can roll themselves completely up into a ball. The eight valves and the skin together may be taken to represent the shell of the Limpet. Underneath is a small head, with mouth, jaws, and long armed tongue, the teeth being arranged in very peculiar patterns. The young *Chitons* have very little resemblance to their parents. They are divided into two nearly equal parts, head and body, with a pair of eyes between. There is no trace of foot, gill, or even mouth; nor of the swimming fins almost universal in young marine Gasteropods. They appear to change their fluids and grow by suction, and to move by a fringe of feelers round the neck. Presently however the body half develops lines on the back, between which gradually seven of the valves are formed, the shelly matter first appearing in granules, as in the land snails. At the same time a foot

spreads out below, and gills between the upper and lower portion. These gills are not like the single long gill of the Limpet, curled round; but are two long, symmetrical organs; it being the fashion of Chitons to double almost everything, the generative orifices included. The head gradually becomes smaller in proportion, is covered with granules which become the eighth valve, and develops a slit, which becomes the mouth. It then loses the eyes; the head never stretches beyond the valves, and there are no tentacles.

The *Chitons* live chiefly on rocks and under stones at low water and in moderate depths. They are sluggish creatures, and apparently neither disturb others or are themselves disturbed, (except by conchologists.) They are found in all seas; but the finest species are not found in the tropics. The largest are from the colder western rocks of North and South America. Different as the *Chitons* are from all other living creatures, they are very like each other. The different groups are not generally confined to particular shores; but the *species* do not travel so far as Limpets and ordinary mollusks, as, indeed, we might suppose from the young having no swimming fins. A large number of genera have been proposed by modern authors, of which the following are the principal; writers unfortunately not agreeing on the group for which the old name should be retained.

The true *Chitons* have the mantle covered with smooth scales, and the end valves elegantly pectinated at the edge; the back valves having the apex raised. *Enoplochiton* has the scales long and unequal; the back valve with smooth edge and depressed apex. In general the middle valves have only one notch; but in *Radsia* there are two; and in *Callochiton*, the edges are cut into four bifid lobes. In *Lepidopleurus* the valves are thin, and easily fall off; the insertion-plates being inside the colored parts. The mantle-scales are extremely small. In *Leptochiton*, which includes most of the northern forms, the scales are minute, the gills short, and the insertion-plates rudimentary, without notches. In *Lorica* and *Schizochiton*, the mantle and last valve are slit behind. They have very minute scales, and in the latter group the valves are very small as compared with the mantle.

In the next series, the mantle is covered with thick hairs or bristles. *Acanthopleura* has the insertion-plates pectinated. *Corephium* has the mantle-spines shelly, and the back valve not lobed at the sides. *Mopalia* has the mantle much produced in front, and narrowed behind.

A comparatively small group *Tonicia* has the mantle naked and smooth. One species, in which the valves are more separated, has been dignified by Dr. Gray with the classical generic name *Fannyia*.

The Oregon district produces a curious group of *Chitons*, in which the valves are nearly or entirely covered by the fleshy mantle. The commonest species, which was first sent to the British Museum by Lady Katherine Douglas, and therefore called by Dr. Gray *Katherina Douglasiæ*, (*Anglicè*, Douglas's Catherine,) has the valves partly exposed and the skin smooth. The giant *Cryptochiton*, the anatomy of which has been so carefully described by Dr. Middendorff, has gritty particles in the rough skin. There is no sculpture on the valves,

which are quite hidden ; the creature looking outside only like a lump of leather.

Another main division of the *Chitons* contains creatures which have pores in the mantle margin ; always nine on each side, and armed with bristles. The great *Plaxiphora* of the Cape Horn district has irregular bunches of bristles, some of them shelly. The shells of *Acanthochites* are beautifully adorned with regular tufts of bristles, which are often of pearly hue. *Amicula* is almost covered by the hairy mantle, like *Cryptochiton*. In *Cryptoconchus*, the tufted pores are at a distance from the edge; and the exposed parts of the valves are extremely narrow. Lastly *Chitonellus* has a long, narrow, fleshy, slug-like body, with very small and separate valves, adapted to crawl in the crevices of coral rocks.

Valves belonging to the *Chiton* group have been found in most geological periods, from the Silurian age downwards. In one of the Silurian forms, called *Helminthochiton*, the valves were separate from each other, but not covered by the mantle.

Order CIRROBRANCHIATA. (*Tuft-gilled Crawlers.*)

Family Dentaliadæ. (*Tusk-Shells.*)

The tooth-shells form a very peculiar and degraded group, which it is the fashion to arrange near the Key-hole Limpets, from the fancied analogy of the tubular shell to a drawn-out Fissurella. They have however scarcely anything in common with that beautiful family, and very little with the class of Crawlers. The very Vermetids look down upon them; for they have heads, tentacles, and eyes, while these have none. The animal is scarcely raised above the bivalves, except that it feeds upon them. The foot is conical and funnel-shaped, opening into the stomach, which is armed with a gizzard, as in the *Bullas*. In fact they belong rather to the Opisthobranchiate division, the fringe-like gills being behind the heart. The blood is red, as in the worms: the breathing organs symmetrical, as in the *Chitons*. They have however a lingual ribbon, in three series, on a very simple plan. They live in rather deep water, where they prey on Foraminifera and small bivalves. Just as the shell of *Vermetus* resembles *Serpula*, so the shell of *Dentalium* often might be mistaken for *Ditrupa*, also a sea-worm. The *Ditrupas* however generally have a swelling behind the mouth, while that of the tooth-shells is plain. In the group *Entalis*, there is a slit at the side of the anal hole. Often a small tube is protruded beyond the hole, which is not a constant character, even in the species.

Sub-class PULMONATA.

(*Air-Breathers.*)

We have already passed under review many of the air-breathing mollusks, which by their general affinities seemed more nearly related to the marine tribes. The mere fact of crawling on land rocks and plants instead of river and shore ones, does not necessarily imply any great

diversity of structure. Between the habits of the amphibious Periwinkles, which crawl half a mile from shore, and the Marine Snails which are always picked up with sea shells; or between those of the freshwater snails and freshwater Periwinkles, which are found entangled in the same group of confervæ; there need not exist any essential difference. The animals of the true Pulmonates however are formed on a lower type from those of the ordinary Sea-crawlers. The senses are less acute; and the individuals perform the functions both of male and female to each other. The breathing cavity, instead of being open, as in the air and Water-breathing Prosobranchs, is a chamber lined with minute blood-vessels, and open only at a small hole. This is closed by a valve, to shut out the water in the aquatic tribes, and the hot dry air of summer days in the land species. The shape and way of crawling of the snails is too well known to need description. They are all fond of moisture, and more or less slimy. In the extremes of heat, cold, and drought, they shut themselves up in corners or under ground, and often make a false operculum, pierced with a minute breathing hole, which is thrown off when the genial season begins. In damp mornings and evenings they are in their glory, munching the luxurious vegetation, and leaving their slimy track behind them as they crawl. They were esteemed a great delicacy by Roman epicures; and are still extensively eaten, both in Europe and South America. The young snails do not undergo any transformation, like that of the pteropodous infants of the Sea-crawlers; their diffusion being sufficiently provided for by ordinary locomotion. Snails are found everywhere, from the Arctic regions to the equator, but are rare in dry and silicious districts, plentiful wherever there is lime and moisture. The continental species are diffused over very wide areas; but the islands of the tropical seas have each their own peculiar forms, even if very near to each other, or to the main land. Supposing a traveler brought back the snails from a West Indian island, an experienced conchologist could tell at once where they were collected; but it would be almost impossible to tell the same from the vast expanse of the various United States.

Snail shells are always lighter than sea shells, having to be carried on the back of the animal without the watery support. Their construction is much simpler, abounding in animal matter; and they are first formed, like the *Chitons*, by shelly granules deposited in the horny layer. Some of the groups are ovoviviparous. The great Brazilian snails lay eggs with hard shells, as large as a pigeon's. In some groups, the shell is little more than horny skin; and in many, the animal is too large to be withdrawn into it. Some families indeed have no shell at all, or only a plate protecting the most delicate organs. The tongue-membrane is not a long ribbon as in the sea-shells, but a short broad horny layer; partly spread over the soft tongue partly curled up at the side. It is covered with an enormous number of minute square teeth, very similar in pattern, and looking not unlike a tesselated pavement, with raised knobs.

Tribe I. Geophila. *Land Snails.*

Family Helicidæ. (*True Snails.*)

The true snails have their body distinct from the foot, and protected by a spiral shell. The shape of this is extremely variable, presenting differences much greater than is usual between widely distinct families in the marine tribes. Yet the different forms pass into each other by such insensible gradations, and the animals are so like in all essential particulars, that the division into genera is a matter of great difficulty. There are many myriads of species from all parts of the globe, and from all kinds of habitats. Many species have been found on mountains from 8,000 to 11,000 feet high, both in the Old and New World, while others live in marshes, or on the sea-shore. In some few groups, both animal and shell present well-marked peculiarities; others are restricted to special districts; but in general the sections are constituted for the convenience of identifying species. How long the snails have lived on the surface of our globe it is impossible to say, as the remains entombed in rocks are almost exclusively of aquatic productions. Nevertheless many snails have been washed down into tertiary strata; and it is singular to find forms and even species now peculiar to the New World, such as *Megaspira*, *Proserpina*, *Glandina*, and *Stenotrema*, fossil in the European Eocene; showing that existing forms have long outlived existing continents. The oldest snail known is a little *Pupa*, found by Prof. Dawson, in situ, on the fossil trees in the coal measures of Nova Scotia; generically it exactly resembles existing forms.

The "horns" of the snails are in reality very long and sensitive eye stumps. The true tentacles are short, and nearer the mouth. They have a saw-like upper jaw to bite the leaves, and plain teeth arranged in squares. The nose, or lung valve, is just under the right side of the shell; the reproductive orifice under the right eye stalk. Some of the European species form and dart out minute needles, it is supposed to attract their mates. The old genera of Lamarck may be taken as sections, from which the immense multitude of species now known require to be subdivided.

The true snails have a short spire, and a mouth rather broader than long. The eatable snail, *Helix pomatia*, (which is believed to have been introduced into South Britain by the Romans for epicurean purposes,) and its congeners, have a semicircular mouth and rather thin lip. *Eurycratera* has a thin shell and very capacious body whirl. *Helicostyla* comprises the tall, compact snails of the Philippines. *Acavus*, which abounds in the Old World, has the mouth somewhat produced in front, and the lip thickened all round, without umbilicus. The group *Caracolla* has the lip continued all round, the spire flattened and generally keeled. In *Lucerna* the mouth is more or less twisted, with teeth; and in *Anostoma* the adult shell is turned upside down, the mouth joining the apex. *Lychnus* is an Eocene *Anostoma* without teeth. *Tridopsis* contains the ordinary American toothed snails; the flat, many-whirled forms being called *Polygyra*. *Geotrochus* contains the conical, thin, flat-based snails, shaped like *Calliostoma*. *Solariopsis* contains the snake-skin snails of tropical America. *Macrocyclis*

resembles it in form, with swelling whirls, and circular expanded mouth. *Iberus* is a common group in the Mediterranean region, also found in California; flattened, often keeled, with the mouth bent downwards. *Ochthephila* abounds in the Canaries, with the lip continued all round, as in *Caracolla*. *Hygromia* contains the small, flat, umbilicated snails of temperate regions, with sharp, rounded mouths, thickened within.

The *Helicella* tribe have the margin quite sharp, and the shell thin and glossy. They live in dark, damp places, and are remarkable for the lingual teeth being pointed at the sides. The shells of *Discus* resemble them, but are not glossy. Those of *Zonites* are rough above but glossy below. The curious Jamaican group *Sagda* has a stumpy, elevated shell, with many whirls, and laminæ running along the inside of the base. *Pitys* is angular, with the mouth variously toothed. The shells of *Stylodonta* have the pillar twisted like *Achatinella;* and those of *Streptaxis* have the pillar curiously distorted.

The *Bulimus* group are like snails drawn out into an oval, the spire being raised, and the mouth longer than broad. There is generally a plait or fold on the pillar. The typical *Bulimi* of South America are six inches long when adult, and an inch when born. Their eggs resemble a pigeon's. The animals are exactly like those of the typical snails. *Cochlostyla* is a Philippine group, with the mouth somewhat rounded and passing into *Helicostyla*. The shells of *Orthalicus* are thin, with a sharp lip; those of *Bulimulus* approaching *Pupa* in form. The *Partulas* are an ovoviviparous group, living on low bushes near the sea in the Pacific islands. *Otostomus* is a South American group, with very long narrow mouths. The shells of *Odontostomus* are curiously toothed, like *Pupa;* and *Tomigerus* has a wry mouth, twisted upwards as in *Anostoma*. The shells of *Cochlicella* are many whirled, like *Cylindrella*. *Chondrus* has a tooth close to the suture. *Zua* is glossy like *Helicella*. *Azeca* resembles it, with a ringent mouth. The shells of *Bostryx* have the last whirls separated, as in *Vermetus*.

The *Achatina* group resemble *Orthalicus*, with the bottom of the pillar truncated like *Melanopsis*. The typical species are African, and are the largest land shells known, being eight inches long. *Limicolaria* forms a transition to *Orthalicus*, with the pillar pinched, not truncated; and *Pachyotis*, a group which lingers in the islands of the South Atlantic, forms a similar transition to *Odontostomus*. The West Indian group *Pseudotrochus* has a porcellanous, highly painted shell. The group *Columna* is many-whirled, like *Cochlicella*. The little *Cionellas* are glossy, and scarcely truncated. *Spiraxis* has the pillar bent; and the large group *Achatinella*, which culminates in the Sandwich islands, and is ovoviviparous like *Partula*, has a sharp, twisted fold on the pillar, instead of a truncation. *Tornatellina* nearly resembles it, but with additional plaits.

The *Chrysalis* snails are remarkable for being narrowed at each end. They are all rather, and some extremely small, and have many whirls. The foot is very short; and the true tentacles very small or altogether wanting. The *Pupas* are very stumpy shells, generally ribbed outside; and with the mouth often curiously distorted by plaits.

In the animals of the little wry-mouthed *Vertigo*, the tentacles can-

not be seen. *Boysia* is a *Pupa*, with the mouth turned up, as in *Anostoma*. *Gibbus* is a group of irregular shells, intermediate between *Pupa* and *Bulimus*. The shells of *Clausilia* are drawn out at each end, and are always reversed. The animals have the great peculiarity of having a kind of operculum (*clausium*) which moves on a leathery hinge, and fits between the teeth of the mouth. They greatly abound in the old world; but only three species have been found in the whole of America. They are represented in the West Indies by the beautiful group *Cylindrella*, in which the mouth is round and the lip reflected. The upper whirls, which would make the shell too long to be carried, are generally thrown off; but the mouth in some species is produced to so enormous a distance that the animal must carry its shell poised in the air, like a pole held at one end. The polished *Cylindrellas* are called *Leia*, answering to *Zua* among the *Bulimi*. The little reversed shells of *Balea* are like a young *Clausilia;* and *Megaspira* is like a very produced *Pupa*, with plaits on the pillar.

The next group consists of snails, which, though they do not live in the water, are never found far off. Their eye-tentacles are short and stumpy, and the animal is fleshy, and not fully drawn into the shell. This is scarcely calcareous, being rarely more than a spiral skin, generally of an amber color. The *Succineas* are very common in marshy places, and easily known by the very loosely spiral shell, with long mouth and pointed spire. *Amphibulima* has the mouth expanded and pinched at the top. *Simpulopsis* has more the shape of ordinary snails. In *Helisiga* the spire is extremely small; and in *Omalonyx* it is almost obsolete, the mantle of the animal being reflected over the sides, as in *Vitrina*.

Family Vitrinidæ. (*Glass-snails.*)

The *Vitrinas* are intermediate between snails and slugs. They can never entirely enter their shells; and, when they crawl, the sides of the mantle more or less overlap the edges. The shells, like those of *Succinea*, are little more than spiral skins, and are generally snail-shaped, and green. A passage to the true snails is provided in *Pfeifferia*. In *Daudebardia*, the tail is very short; the little shell lying at the back of the animal, as in *Testacellus*. The shell of *Peltella* is shaped like the Sea-ears, and is entirely hidden by the mantle. *Cryptella* is the slug of the Canary Islands, which hides itself the greater part of the year, and then makes sad havoc of the gardens in the rainy season. It has an irregular shell, which in the very young state is provided with an operculum; but afterwards it is entirely covered by the mantle-shield, on the back of the broad animal. The African tribe *Parmacella*, have a similar shell, similarly hidden. The foot is truncated behind, thus passing into the next group.

Some of the *Vitrinas* have the tongue-teeth hooked at the sides, and are supposed to feast on animal substances. The *Stenopus* tribe however have a horny, saw-shaped jaw and teeth, after the model of the true snails. They resemble the *Vitrinæ* in having mantle-flaps partly covering the shell; but differ in having the foot truncated behind, with a slime-gland at the end. The shells are horny and polished

like *Helicella*. The large tropical group of *Nanina* have the sole of the foot broad. In some of the sections, the shell is rough above. In *Arioptranta*, there are no mantle-flaps, but the slime-gland is still seen behind the left-handed shell. *Helicarion* has a Vitrinoid shell, nearly enveloped by the flaps of a Naninoid animal. The animal of *Paryphanta* is not known; but the shells are like a large horny *Vitrina*.

Family TESTACELLACIDÆ. (*Carnivorous Snails.*)

The great *Glandina* of South Carolina, and its congeners, have the lingual teeth in curled rows and sharply hooked. The head is short, and the lips are produced into false tentacles, as in the *Ampullarias*. The shell resembles a flattened *Achatina*. It is strictly carnivorous in its habits.

A curious little group of slugs are found to have similar dentition and habits. The teeth are pin-shaped. They are known from the common slugs by not being slimy; living under ground, where they prey upon earth worms; and having a little solid shell like a Sea-ear on its tail. Its head however is shaped like the True Slugs. A similar, but somewhat apocryphal slug is figured by Férussae, with a horny, conical shell on the tail; it is provisionally called *Plectrophorus*.

Family LIMACIDÆ. (*Slugs.*)

The True Slugs have teeth very like *Vitrina*, but the points are longer. The body of the animal is united to the foot, and a shield is seen on the back, under which, in *Limax*, there is a calcareous plate, which has been found fossil in the Eocene beds. They are pretty active in damp weather, and love to feed on decaying animal and vegetable matter. The Teneriffe Slug, *Phosphorax*, has a bright green spot on the tail, which shines at night like the glow-worm. In the *Philomycus* of the southern States, the shield covers the whole back of the Slug.

The *Arions*, or Land-soles, have only a few granules instead of a shelly plate, and have a slime-gland like *Nanina*. The common English species has 160 rows of teeth on its tongue, with 101 denticles in each row. They freely eat dead worms; and, like true cannibals, will not refuse to finish off an injured individual of their own species. The Irish Slug, *Geomalacus*, has a shell like *Limax*, and a gland like *Arion*. The reproductive orifice is under the right eye-stalk, as in the True Slugs; in the Land-soles, it is just below the breathing valve.

A very curious New Zealand Slug, *Janella*, resembles *Philomycus* in having the mantle produced over the whole back; but the eye-stalks are behind the forehead, and the mouth beneath, at the front of the foot-sole; so that the head is hardly distinct. The mantle is grooved down the middle, and the breathing hole is half way down the body. The creature coils itself round to sleep like a cat.

Family ONCIDIADÆ. (*Rough-Slugs.*)

The *Oncidia*, like the *Auriculus*, live in damp places near the sea or

rivers. They are short, stumpy creatures with a rough skin, and closely resemble some of the Sea-slugs. Their eyes are at the end of the stalks, which are not retractile. The teeth are like those of snails, but they have no horny jaws. The breathing hole, vent, and ovary are at the back of the body; the intromittent opening under the right eye. *Oncidella* has flaps round the mouth. *Peronia* lives on shores, moving up and down a few feet above tide level. These Slugs have knobs or excrescences on their backs, as well as flaps round the mouth. The British species is said to have the heart in front of the lung, while in all the other pulmonates it is behind.

The *Veronicella*, which lives in damp, shady forests, has a smooth, leathery mantle, and a pair of small, bifid tentacles in addition to the eye-stalks. The ovary opens half way down the side. These Slugs crawl quickly, and are not slimy. They lay their eggs in a coiled necklace.

Tribe II. Limnophila. (*Aquatic Snails.*)

The amphibious tribes differ from the true land snails in having no eye-stalks. The tentacles are generally short and stumpy, and the eyes are fixed at their bases, as in the Periwinkles. The tongue-teeth greatly resemble those of the snails.

Family Auriculidæ.

The *Auriculas* were long regarded as sea-shells. They inhabit salt and brackish marshes, and their shells are much more solid than is usual with land-shells. Some of them absorb the inner whirls like the Nerites. The shells always have narrow mouths, more or less toothed.

The typical *Auriculas* sometimes have large shells, and increase half a whirl at a time. They have a stumpy spire, long narrow mouth, thickened inside, and a few large folds on the pillar. They rejoice in mud banks in the East Indian archipelago. The animal of *Cassidula* has the foot cleft behind. The shell is stumpy, and the thickening of the outer lip wrinkled. The shells of *Scarabus* are conic and rather thin, being adapted to a true terrestrial life. The whirls have two rows of indistinct varices, and the mouth is strongly toothed on each side. The little *Alexias* represent the previous groups in the Atlantic regions: having a plain and pointed spire. The tiny *Carychium* resembles *Pupa* in form, and lives in moist places far off from the sea.

The *Melampus* tribe enjoy sea bathing, though strict air-breathers. Their foot is cleft behind. Their shells resemble *Cassidula*, but the outer lip is either thin or regularly toothed within. Some species, called *Tralia*, are said to have a pointed foot. The tentacles in these animals are sharper than in the less aquatic species. The Sandwich Island group *Lœmadonta* have a curious plait across the outer lip. The shells of *Leuconia* have a sharp outer lip; and the animal is said to differ from *Alexia* in having the foot grooved across. The shells of *Pedipes* have a very wry mouth like *Scarobus*, and a very short spire. The animal has a grooved foot, and loops in walking like *Truncatella*.

It steps about, more quickly than most mollusks, in rocky crannies on the sea-shore.

Family OTINIDÆ. (*Ear Snails.*)

The little shell of *Otina* could hardly be distinguished from *Velutina* but the animal closely resembles *Auricula.* The tentacles are very small; the foot grooved for looping; and the mouth cleft vertically. The little creatures live in the same situations as *Pedipes.*

Family LIMNÆIDÆ. (*Freshwater Snails.*)

In company with *Melanias*, *Paludinas*, and other gill-breathing freshwater Periwinkles, are found in every part of the globe shell-fish which never leave the water, and yet are as truly air-breathers as the whales. They must needs come to the surface occasionally to breathe, where they may be seen gliding upside down, and sometimes letting themselves drop at the end of a glutinous thread. They have short, stumpy tentacles, with eyes on the inner basis, and very broad feet. They abound most in temperate regions. The breathing hole is at the right side of the neck: the vent at the left. They lay their eggs in gelatinous masses on the leaves of water plants which they devour. The *Limnæa stagnalis* has 110 rows of 111 teeth each, and is said to prefer feeding on decaying animal matter. The shells of *Limnæa* are thin, with a pointed spire, and a fold on the pillar. Those of *Chilina*, which inhabit the clear running streams of South America, are almost exactly like *Auricula*, which the animals of this family greatly resemble. The shell of *Amphipeplea* is transparent and swollen; and is nearly covered by the sides of the mantle.

Family PLANORBIDÆ.

The animals of this family differ from the Limnæids in having sharp, pointed tentacles. The shape of the shells is extremely variable. In the first group they are flat, in the second pointed, and in the third limpet-shaped.

Planorbis has a spiral shell with the whirls inclosing each other on the same plane. It lives in a reversed position. The whirls are flat and numerous in most of the European species; generally few and swollen in the American. Monstrosities are found, perpetuating themselves in particular ponds, with the spire elevated. The teeth closely resemble those of *Auricula.* One of the minute British species has no fewer than six thousand of them. Some species emit a purple fluid when disturbed. In *Segmentina* the whirls are divided across at regular intervals, by septa with toothed openings for the passage of the animal. So little was known of its true relations in earlier times, that the British species was called the "Freshwater Nautilus."

The *Physa* tribe have shells looking like reversed *Limnæas.* In the typical species they are enveloped, as in *Amphipeplea*, by the fringed sides of the mantle. In the beautiful group *Aplexa*, the shells are glassy, with raised spires, and the mantle margin is plain and not flapped. *Physopsis* is a south African form, like a reversed *Achati-*

nella: and the East Indian *Camptoceras* has the whirls separated like *Vermetus*. Fossils of this tribe, as of *Limnæa* and *Planorbis*, are found as old as the Wealden oolitic rocks.

The limpet-like shell of *Ancylus* is as different from *Physa* as *Broderipia* from *Trochus*, or *Testacellus* from *Glandina*. Nevertheless the animal is even more closely allied. The shell is sinistral, (the point being turned to the right,) and entirely covers the animal; which has much less attachment to it than the Limpets, and can move its long neck freely under its large umbrella. *Velletia* is a dextral shell, with the apex turned to the left, and a somewhat different arrangement of teeth. Both forms are found fossil in Eocene strata. The curious little New Zealand *Latia* has a deck across one end, like the Slipper-limpets. Lastly, the Cuban *Gundlachia* has the knobby apex produced, and the deck broad, so as to resemble some of the small-spired *Neritinæ*, but without operculum. All these curious freshwater Limpet-snails crawl on stones or plants, generally in clear water.

Tribe III. Thalassophila. (*Marine-snails.*)

These curious creatures are always found close to the sea. The animals greatly resemble *Auricula*, and have the normal dentition of Helix. The inside of the breathing chamber is wrinkled, so that it would appear that neither air nor water would come amiss. The cavity is however closed as in the true snails, and wet sea air is probably most congenial to them. The small tentacles are flattened out into a disk round the head.

Family Amphibolidæ. (*Periwinkle-snails.*)

These creatures have shells somewhat like a *Natica*, with the outer lip somewhat notched, as though for an air passage. They are eaten in New Zealand like Periwinkles, and differ from all other true Pulmonates in having a thin, horny, sub-spiral operculum. There is only one genus known, *Amphibola*, from the Australian seas.

Family Siphonariadæ. (*Sea Limpet-snails.*)

The *Siphonarias* have solid, conical shells, often overgrown with sea-weeds and nullipores. They are known from Limpets by their irregularity of form, caused by a groove which interrupts the muscle of attachment on the right side; not traversing it, as in *Gadinia*. They are found on almost all tropical shores. There is a large mantle-flap covering up the breathing hole. The tentacles are entirely flattened down into a veil; and the animal has a much plainer appearance than the ordinary Limpets. The individuals in many species vary more, in shape and sculpture, even than in their water-breathing neighbors. These creatures are to the *Amphibolæ* what the *Ancylus* is to the *Planorbis*.

Sub-Class. OPISTHOBRANCHIATA.

The next division of the crawling mollusks consists of creatures which are generally destitute of shells, or simply have them as a pro-

tection to particular organs of the body. The gills are not lodged in a special neck-cavity, but are *behind the heart*. The sexes are united in each individual. In the young state, they are exactly like the fry of the prosobranchs; each being inclosed in an operculated spiral shell, and furnished with pins and *cilia*. They are all inhabitants of the sea. They are formed on two distinct types; those in which the gills are at the side, more or less covered by the mantle, and often protected by a shell; and those in which the gills are exposed, and entirely destitute of shell. They live principally on animal matter.

Order I. TECTIBRANCHIATA. (*Crawlers with sheltered gills.*)

Family Tornatellidæ.

The animals of this tribe are as yet but little known. They are arranged by Dr. Gray between *Scalaria* and *Cerithiopsis*, on the supposition that the gills are comb-like and the animal unisexual. It is curious how large a proportion of existing observations on mollusks need verification by those who have honest, well-trained eyes. Just as the infant's eye has to be trained to distinguish forms and distances, so it requires practice before we know how to see truly an object that lies before us. During the educational process it is often very easy to see what we wish or expect to see. The shells of this tribe are nearly allied both to the *Pyramidellids* and the *Auriculids;* and some aberrant forms show relations both to *Ovula* and *Dolium*. As the living forms are confined to a very few species, it is scarcely to be expected that we should be able rightly to assign the positions of the various fossil groups. These are found in great numbers, beginning with the coal strata, becoming very plentiful in the oolites, and culminating in the cretaceous age. The ordinary sculpture of the tribe is in spiral lines or rows of dots. They differ from all the other Opisthobranchs in having a very thin operculum, with broad, thin flaps, so as completely to cover the mouth. The animal is quite retractile into the shell, and has the general aspect of an *Auricula*, with its short, flat, triangular tentacles and the eyes at their front. The teeth however are widely different. Instead of the thousand tessellated teeth of the snails, there are simply two rows of sickles arranged as an arrow head on the narrow, broad tongue. They live in rather deep water, and are by no means common in collections. The tentacles are used rather as a veil than as feelers, being laid over the front of the shell in walking. The gills are at the side, cloaked over by the mantle.

The shells of *Tornatella* proper are thin, with one fold on the pillar. Those of *Buccinulus* are stout, with two folds. (*Monoptygma* may prove to be an elongated *Tornatella*, with a single, slanting fold.) All the remaining genera are fossil. *Acteonina* is like a *Monoptygma* without plait. The oolitic *Cylindrites* have the folds twisted outwards. The chalk *Acteonella* is like a cone-shell with plaited pillar, but without breathing notch. *Cinulia* has a globular shell, with many-plaited pillar, and toothed outer-lip. *Globiconcha* has a similar shell without the plaits. *Varigera* resembles it, with varices like *Scarabus*. In the Portuguese *Tylostoma*, varices are formed thickened inside as in *Cassis*.

Pterodonta is notched in front, in which respect it resembles the living *Ringicula*. The shells of this genus are very small, and have been passed on from one place to another, like an English pauper. They have a wry mouth with strong pillar-plates, and a notched lip, somewhat like *Malea*. They probably form a family by themselves, differing from *Tornatella* in their glossy texture.

Family Cylichnidæ.

In this tribe the teeth are arranged in thirteen longitudinal series, greatly resembling *Fissurella*. The shell somewhat resembles a *Tornatella* without plaits, with the spire more or less concealed, and the aperture pinched behind, swelling in front. In some of the forms the apex is prominent and reversed, as in Pyramidellids. The tentacles are united into a broad veil, looking something like a *Natica* as the creature ploughs through the wet sand. There are however small eyes in front. The deep-water *Cylichna* has the spire concealed. In the littoral *Utriculus* it is raised; and in *Tornatina* there is a columellar fold, and a channeled suture. Certain little shells, closely resembling *Radius*, have been referred to this family, till more is known concerning the animals. *Volvula* has a posterior canal like the Egg-shells, but a fold on the pillar like *Tornatina*. Some curious fossil forms appear to belong to this group.

Family Amphisphyridæ.

In this little group the shell closely resembles *Utriculus*; but it is transparent, the eyes being placed behind it, as in *Jeffreysia*. The tentacles also are like side-fins, and the animal shuts itself up entirely in its shell. The teeth closely resemble *Tornatella*, but with a square key-stone between the rows of sickles.

Family Aplustridæ.

The shells of this family are generally very highly colored, and are partially covered by the expanded foot-lobes. The animals, also, are highly tinted, and adorned with flap-like tentacles, with eyes at their bases. The tongue-teeth resemble *Tornatella;* so does the pretty little shell of *Bullinula*, which has a twisted, but not plaited pillar, notched at the bottom. *Aplustrum*, which abounds in the Sandwich Islands, also has a twisted and notched pillar, with a membranous outerlip and flattened spire. In *Hydatina*, the pillar is simple.

Family Bullidæ. (*Bubble-shells.*)

The shells of this family resemble an *Ovulum* without canals, and with sharp lip. The apex of the spire is generally perforated, and the shell adorned with cloudy painting. The teeth are in arrow-headed rows of sickles, with a hooked key-stone. The *Bullas* love slimy places, where they grub for bivalves and other mollusks. The shells of *Haminea* are thin and horny, almost inclosed by the broad flaps of the foot and head. *Acera* has a similar shell, but more flattened, with

a slit at the suture, through which a mantle tail runs, as in the Olives. The animal has a very long head, but no eyes. This is also the case with *Atys*, the shells of which are strong, white, and generally notched on each side of the lip.

Family PHILINIDÆ. (*Open Bubble-shells.*)

The shells in this family are never completely rolled-round, but the point of the spire can be seen within. They are situated at the tail end of the animals, which never wholly enter them. The teeth of these creatures consist of two (rarely four) longitudinal series of sharp sickles, turned upwards and often serrated within. Sometimes there are small, buttress-like teeth outside. The animals, like the rest of the Bubble group, have the tentacles merged into the frontal veil, making the head wedge-shaped, for swimming or gliding through soft mud, the resting-place of unsuspecting bivalves. While the blind *Naticas* deliberately drill their hole and suck out the soft flesh, the dull-eyed Bubbles gobble them down, shells and all, and send them to their gizzard-mill to grind. This consists of three shelly plates, much thicker than the shell-covering of the animal, and working together by means of strong cartilage. An old Italian naturalist called the plates of this gizzard *Gioënia*, after himself, and described the habits of the invented animal; so that even Lamarck and Cuvier were deceived by it.

The first group never cover their shells. That of the *Scaphander* is very large and swollen in front; narrow and projecting beyond the blind animal behind. The green, somewhat pearly shell of the Pacific group *Smaragdinella* is placed on the middle of the back; the spire being represented by a cup-like process, as in *Calyptræa*. The creature has its tiny eyes in the middle of the veil. *Phanerophthalmus* has a horny plate, scarcely bent-in on one side for a spire, at the back of the animal, and partly covered by the foot-lobes. *Cryptophthalmus* has a similar shell, with the eyes behind the veil.

In the next group the shell is colorless, and entirely covered by the mantle, at the back of the body. The animals have no eyes. *Philine* has a very open, slightly-spiral shell, *Doridium* a flat, triangular plate. *Chelidonura* has a thin, slightly curved, ax-shaped shell. The animal is very brilliant, with two long tails behind.

The animals of *Gasteropteron* and *Posterobranchæa* require more careful examination. They have no shell, and may belong to another group.

Family APLYSIADÆ. (*Sea-hares.*)

In the remaining families of Tectibranchs, the head is drawn out, and the tentacles are distinct. They present the general aspect of Sea-slugs, and, like their land allies, have often a shelly plate to protect the vital organs. The tongue-teeth are arranged in very numerous longitudinal series, in angular cross lines. The sea-hares are grotesque creatures, which crawl about among rock-pools, living on a mixed diet. They have ear-shaped feelers, with eyes at their bases; a fat body, under the skin of which is an irregular shell, and often rough with

hairy or knobbed ornaments, and produced into a tail; and side-flaps to the foot which may be used for swimming. When disturbed, they discharge a beautiful violet fluid from the skin. The harmless "Unwashables" (*Aplysia*) were formerly dreaded by fishermen, who thought their stains were poisonous and indelible. They have a convex, horny plate covering the gills; and sometimes old Sea-hares have several of these, one inside the other, as in the Cuttle-pens. They have a cartilaginous gizzard, like the Bubbles. In *Syphonota* there is an excretory tube above the tail. *Dolabella* has the plate shelly, and generally ax-shaped.

Aclesia is like *Aplysia*, without shell or swimming flaps. In *Stylocheilus* the neck and tail are very slender. *Notarchus* has the body rounded, with a very narrow foot for adhering to floating sea-weed. *Bursatella* presents a most anomalous appearance. The common observer might take it for a jelly fish: for it is quite round, with only a rudimentary foot, and with a mass of branched ornament. This consists, however, first of a large gill hanging out of the back; and secondly, of the tentacles which are cut up into branches.

Family Icaridæ.

A small family of Sea-slugs have a Bulloid shell, not covered by the mantle, and only two stumpy tentacles, instead of four, as in *Aplysia*. The body is thin, with a very long tail. The shell of *Icarus* resembles *Amphisphyra*, with a notch at the suture. *Lobiger* has a thin shell shaped like *Pedicularia*, with four spreading foot-laps, adapted for swimming, like the Pteropods.

The remaining families differ from the Bubbles and Sea-hares, in having the reproductive organs close together, in one tubercle.

Family Pleurobranchidæ.

These animals have four stomachs, but very short intestinal canal. They are sluggish, compact, often large, and have a somewhat retractile proboscis. The head is hidden under the edge of the mantle, with two tentacles and eyes. The gill is at the side, not on the back as in *Aplysia*. *Pleurobranchus* has a thin, flat horny shield, and a very large foot. The mantle in *Oscanius* is irregularly expanded, and the shield silvery. *Susania* has a plain body, with very small shield, and a large mantle deeply notched in front.

Pleurobranchœa and *Neda* have no shield, and a very small mantle. The former has a narrow, the latter a broad foot.

Family Umbrellidæ. (*Chinese Umbrella Shells.*)

Again we come unexpectedly on a group of Limpets; for so the shells might be considered. The *Umbrellas* are very large creatures, wearing a flat limpet on the middle of the back; not immersed in the mantle, as in the very differently organized *Lucapina*. The gill is below the shell, on the right side. The foot is enormously large, and encloses not only the body but the head, which has a retractile snout. Fossil specimens have been found in the Eocene beds. The animal of

Tylodina is intermediate between the *Umbrellas* and the *Pleurobranchs*. The head is produced and cleft in front; the foot small; and the shell shaped like *Scurria*, but membranous, and with a small spiral, sinistral apex. This will probably be hereafter detected in the young *Umbrellas*.

Family Runcinidæ.

The *Runcinas* are tiny Sea-slugs, with gills like *Pleurobranchus*, and hard gizzards like the Bubbles. The tentacles are flattened into the mantle. They are supposed to have teeth in three series, and to feed on *Diatomaceæ*.

Family Diphyllidiadæ.

The Phyllidians are curious creatures intermediate between the Tectibranchs and the Nudibranchs. *Diphyllidia* has gills going round the back two thirds of the body, the plates being folded in front and behind at right angles to each other. The teeth and horny jaws resemble the Bubbles. There is a curious veil in front of the tiny tentacles, resembling a "respirator."

Family Phyllidiadæ.

The *Phyllidias* have the general aspect of a *Cryptochiton*, the gills being arranged all round (except at the head) between the mantle and the foot. They have no jaws or tongues. The lips are small and conical; and the tentacles on the back can be drawn into pouches. *Fryeria* has a rough mantle, and the vent is under the mantle at the back. *Hypobranchiæa* has the mantle extended into swimming flaps.

Order II. NUDIBRANCHIATA.

The Naked-gilled Crawlers form a large tribe of mollusks, of strange forms and marvelous beauty. They are found in all parts of the world, from the arctic to the torrid zones, wherever there is a firm, rocky bottom, or a crop of sea-weed. When first born, they dwell in a little nautiloid shell, with an operculum; and swim freely with a pair of pteropodal fins. Afterwards they drop fins, shell, and operculum, and become sedate Crawlers, breathing by means of exposed gills on the back, which assume various ornamental shapes, and can often be drawn into cavities of the mantle. In some tribes, the skin is coarse and leathery; while in others this and the various tissues of the body are so delicate and transparent that we may watch the beating of the heart and the digestive processes. The British species have been admirably examined by Alder and Hancock, and illustrated by the Ray Society in one of the most beautiful Memoirs ever published. It is probable that they are equally abundant in other parts of the world; but they have been very little observed. They are extremely timid; and when disturbed they draw themselves up into a mere lump of jelly or tough skin, so that ordinary collectors would pass them by altogether; and even experienced naturalists must live in their neigh-

borhood some time before he can dredge and examine the forms which belong to each fauna. As they do not preserve their shapes in alcohol, and leave nothing that can be kept in cabinets or impressed on stratified rocks, they can scarcely be understood without reference to figures; and therefore only the principal groups will be here described. The student is recommended to examine the plates of Alder and Hancock for the British, and of H. and A. Adams for the exotic tribes.

In the first group of families, the gills are on the back, near the tail, and surrounding the vent. The skin is leathery, of a spongy texture, and stiffened with minute darts.

Family Doridæ. (*Sea Lemons.*)

The *Doris* and its allies have tree-like gills, with the vent in the middle. The teeth are in very numerous longitudinal series, resembling the Bullas. They feed on zoophytes and sponges, and lay their eggs in a spiral ribbon, attached on one side. The body is convex; the mantle large, but plain at the sides; and the back tentacles can be drawn into pouches. The gills can be drawn into a general cavity. The genera *Glossodoris*, *Chromodoris*, *Actinodoris*, *Asteronotus*, *Actinocyclus*, *Atagema*, and *Dendrodoris* are characterized by differences in the shape of the gills, tentacles, and mantle. In *Hexabranchus* and *Heptabranchus*, each gill has a pouch to itself; the circle in the latter not being complete.

Family Onchidoridæ.

In *Onchidoris*, the gills are not retractile, and the back tentacles are laminated. The tongue is narrow, with two rows of large teeth (as in *Philine*) and buttresses outside. The other genera are *Acanthodoris* and *Villiersia*.

Family Goniodoridæ.

The *Goniodorids* have a flattened, angular body. The mantle does not reach the head and foot, and the gills are not retractile. The tongue-ribbon is narrow, with four series of spines. The Red Sea *Brachichlanis* has the tentacles in front of the mantle.

The lovely *Idalias* have the mantle almost obsolete, but produced into four false tentacles in front of the true ones, and smaller ones round the gills. In the very curious *Ancula*, (afterwards named "Miranda,") the mantle degenerates into a semi-circular palisade to protect the beautiful bunch of branching gills. The tentacles are elegantly folded at the ends, and below are fringed with spreading feelers. This smooth, transparent, slug-shaped creature, only yet known in the German ocean, glides along, with a spreading moustache above its mouth, carrying its living flower-basket on its back.

Family Polyceridæ.

The "many-horned" Nudibranchs differ from the last family in having twelve or sixteen teeth on the tongue-ribbon. In *Polycera*,

the mantle makes a spiked fringe, surrounding the gills and tentacles. *Palio* has the veil slit in front. The tail of *Trevelyna* is lancet-shaped. In *Thecacera* the mantle is obsolete, and the tentacles retractile.

Family TRIOPIDÆ.

In this family the teeth are in very numerous rows, on a broad ribbon, but slightly hooked. The tentacles are retractile, within plaited sheaths. *Triopa* has a beautiful set of palisades between the mantle and the foot, forming a fan-shaped row of ornamented tentacles above the mouth. Other genera are *Euplocamus* and *Plocamoceros*. *Ægires* has the tentacles smooth, and the teeth uniform.

Family CERATOSOMIDÆ.

Ceratosoma has conical, spiny teeth in uniform rows, with a spiny, somewhat retractile snout. The gills are retractile into a projecting horn-shaped pouch; but not the tentacles.

In the following groups, the gills are scattered over the back of the animal.

Family TRITONIADÆ.

The *Tritonias* are elegant creatures, often large for the order, reaching six inches in length. The gills are arranged in ornamented plates, rising at regular intervals along the mantle-edge. The veil is large and fringed: the teeth in very numerous rows, behind the horny jaws; and the fringed tentacles retractile within the sheath. They live in shallow water, preying on zoophytes, &c.

In *Scyllæa*, the mantle-margin is produced into flaps, bearing the gills on their inner edge. The foot is narrow, and grooved for clasping floating sea-weeds, on which they are borne about.

Family TETHYADÆ.

The *Tethys* has an enormous flat veil, as large as the body, and copiously fringed at the edge. Although it has no teeth or jaws, fragments of crabs and shells have been found in its fleshy gizzard.

Family DENDRONOTIDÆ.

In the *Dendronotids* and the groups which follow, the stomach and liver are curiously spread out and branched. *Dendronotus* has a beautiful row of tree-like gills, along the middle of the back. The tongue-ribbon is broad, with very numerous series of serrated lancet teeth. *Bornella* and *Lomanotus* are other genera.

Family PROCTONOTIDÆ.

In *Proctonotus* and *Janus* the gills look like the stamens of a flower, copiously arranged round the mantle edge. There are strong horny jaws, and the tentacles are not sheathed.

Family DOTONIDÆ.

In this family, the tongue-ribbon is narrow, with a single series of recurved, serrated teeth. The gills are in two rows of shrub-like processes along the back, into which the liver-vessels enter. In *Hero*, *Gellina*, and *Nerea* the tentacles are not retractile; but in *Doto* and *Melibe*, they are slender, and can be drawn into the graceful sheaths which support them like a candlestick.

The *Chiorœra* of Puget Sound may perhaps belong to this group.

Family GLAUCIDÆ.

Glaucus is a very singular creature. The foot is rudimentary, and it swims in the open sea, feeding on Jelly Fish and *Velellas*. The gills are arranged on side-fins, spreading out like the snake-tails on a gorgon's head. The teeth have some resemblance to those of *Amoria* among the Volutes, but are serrated on each side of the point.

Family ÆOLIDÆ.

The *Æolis* tribe are very delicate, graceful, highly ornamented, and beautifully painted mollusks, which live in shallow water, principally preying on zoophytes. In confinement, they have been known to browse on the breathing ornaments of their fellows, or even to devour each other's bodies. The gills are arranged as very numerous stamens, in variously-grouped rows along the back. Into these enter the ramifications of the stomach and liver. The tentacles are generally simple and unadorned. The teeth consist of a single series of semicircular combs. The other generic forms are *Calma*, *Flabellina*, *Facellina*, *Coryphella*, *Favorinus*, *Phidiana*, *Cuthona*, *Cavolina*, *Galvina*, *Tergipes*, *Embletonia*, and *Calliopœa*. In the last genus the back-tentacles are obsolete. They are all characterized by having the last vessel of the liver stomach above the ovary, instead of below as in the previous families: but agree with the others in having only one orifice to the reproductive organs.

Family FIONIDÆ.

In this and the next family there are two openings for the reproductive organs, and two hind vessels for the liver-stomach. *Fiona* has four tentacles, jaws round the mouth, and a fringe on the inner side of each gill-stamen.

Family HERMÆIDÆ.

Hermœa and *Stiliger* have only two tentacles and no jaws. The little *Alderia*, from the salt marshes of Skibbereen, has no tentacles at all.

Family ELYSIADÆ.

In all the previous families, the gills have appeared the most beautiful and important organs of the Nudibranchs. In the rest, they are no longer seen. *Elysia* and *Placobranchus* breathe by means of *cilia*

or fine, soft hairs, spread over the surface of the body; and by plaits or vessels radiating on the back. Their bodies have long swimming flaps; and the branched liver-vessels open into the sides of the stomach.

Family LIMAPONTIADÆ.

In these lowest of Opisthobranchs, as in the lowest of the Heteropods, there are no special breathing organs. The aëration of the blood is carried on entirely through the skin. In general appearance, these creatures are like lungless Slugs. In *Limapontia* and *Actæonia*, the tentacles are crest-like; in *Ictis*, *Fucola*, and *Pelta*, they are linear. The little genus *Rhodope* is like a creeping worm, without mantle, shell, gill, tentacle, or any other appendage. It appears the most degraded of Crawlers, but no doubt enjoys life in its own way as it progresses over the sea-weeds of Messina.

SUB-CLASS HETEROPODA.

The Heteropods, or *Nucleobranchs* as they are sometimes called, are a very aberrant race of creatures; and, as such, placed in very different positions by naturalists. They are in fact Gasteropods, adapted for swimming in the open seas. As they do not crawl on the belly, they have scarcely a right to the name of the class: accordingly some authors treat them as an independent division, between the Gasteropods and the Pteropods. As however we have seen the crawling foot obsolete in the stationary *Magilus* and *Vermetus;* and scraggy, more fitted for leaping, in *Strombus* and *Phorus;* it is no great strain on our general idea of a Gasteropod to imagine its foot flattened into a fin for flapping in the open sea. Many of the Opisthobranchs have the foot developed into side-flaps for swimming: we have only now to imagine the boat propelled by one central scull instead of by a pair of oars. It appears the simplest arrangement to regard them as a group coördinate with the crawling Gasteropods, but inferior to them; as the implacental by the side of the ordinary Mammalia.

In some respects the Nucleobranchs are superior to the ordinary crawlers. Their bodies are more symmetrical and their locomotion more active. Dr. Gray, indeed, arranges *Ianthina* with *Scalaria* among the Proboscidifers, and the remaining groups with the Rostrifers. Nevertheless, the lower tribes are so like the lower tribes of Nudibranchs—which indeed they all resemble in the exposure of their gills; and the whole group forms so natural a transition to the Pteropods, that this appears their most appropriate place. It will be understood, however, that Nature never arranges her creations in straight lines; but the higher animals in one division are commonly more complete in organization than the lower animals in the groups above it: each type producing the highest as well as the lowest within its own sphere.

The Heteropods have the sexes distinct, like the Comb-gilled Crawlers; and, like them, have the gills in advance of the heart. They resemble the Tectibranchs in the subordination of the shell; which sometimes envelopes the whole animal, sometimes only the vital organs,

and frequently is absent altogether. In the delicacy and transparency of their tissues, they resemble *Nudibranchs*.

Family IANTHINIDÆ. (*Violet Snails.*)

Among the aberrant Heteropods, the *Ianthinas* form an aberrant, not a typical family. The shell is very thin, snail-shaped, with a twisted pillar, angular at the bottom, and a slanting apex. The outer lip is always waved, affording a passage for the exposed gills. All the species are of a beautiful violet color, deepest on the under side, which is more exposed to the light when swimming. The animal has a prosobranchiate head, projecting beyond the mantle, ending in a stumpy snout, and armed with two long and two short tentacles. The latter may be regarded as eye-stalks without eyes. As the animals are believed to sleep by day and prey upon the Jelly Fish and Velellas by night, they have no need of them. But the most remarkable appendage is their float, consisting of air-bubbles set in jelly; which is about three times the length of the shell, and attached to the rudimentary foot. Below this the females fasten their eggs. Buoyed up by these bubbles, the ocean-snails float about in shoals in the open seas of warm climates, and are often cast on shore in vast numbers after storms. The teeth are in numerous series, like *Scalaria* and *Bulla*.

There is only one other genus in the family, *Recluzia*, in which the violet color disappears, and the shell somewhat resembles *Jeffreysia*.

Family MACGILLIVRAYIDÆ.

The little swimmers which compose this family have not only a normally-shaped shell, but also an operculum. As this is found in addition to the Ianthinoid float, it proves that the latter does not take its place in the last family, as had been supposed. The animal has a broad swimming fin, armed with an operculum bearing a support as in *Jeffreysia*. A breathing-pipe conveys water to the gills, which are covered in. There are two tentacles with eyes at their bases, and tongues armed with teeth and jaw-plates, as in the typical Pectinibranchs. The most remarkable feature however is the crown of four false tentacles, branching out behind the head like a collar, as in several of the Nudibranchs, and many times the length of the shell. The pretty little *Ethella* has the pillar of the shell pointed in front, and the operculum on an arm like the Strombs. It appears to be used as a shield; while the creature skips and jerks with its complex foot. There is a beautiful collar, composed of six elegantly fringed arms. *Gemella* has a foot like a square-toed shoe, with which it glides along the surface of the ocean. The shell is like a flattened *Recluzia*, with a few whirled operculum. "This shell-protected speck buoys up its tiny body" in the South Pacific, "cast abroad, though not lost, in the ocean's immensity." The singular little shells of *Calcarella* are abnormally spiral, looking more like those of the Pteropods. They are prettily fringed, like *Trichotropis*. The animals have comb-like gills; long, well-armed tongue-ribbons, and massive, armed jaws. They are crowned with eight fringed arms. All the creatures of this interesting and

little-known family are extremely minute. It is very probable that the animal of *Cheletropis* will be found closely allied.

Family Atlantidæ.

The beautiful little glassy *Atlanta*, when first discovered, was supposed to be a recent *Ammonite*. It has a flat, keeled shell, very sharply keeled, and deeply notched like *Scissurella*. The broad, triangular swimming-fin has a little disc, with which it can moor itself to any floating object. The operculum begins as a right-handed spiral, but continues straight. The snout is very long; the eyes and tentacles large, and the neck thin. *Oxygyrus* has a cartilaginous shell, with a triangular, concentric operculum, like the supposed opercula of *Ammonites*. The teeth have a general similarity to those of *Carinaria*.

Family Bellerophontidæ.

The *Bellerophons* are a singular race of ancient fossils, the true affinities of which are not yet agreed on. They are thin, globular, spiral shells; like a *Nautilus*, but without chambers, and displaying a keel or notch in the middle. Some liken them to *Argonauts;* others to *Bullas;* others consider them as enrolled *Emarginulas;* but the best-supported opinion is that they are as it were swollen *Atlants*. The little cretaceous species, without notch, are called *Bellerophina*. The palæozoic species with the whirls exposed are *Bucania*. Those with the whirls scarcely embracing, like an unchambered *Ammonite* with a slit mouth, are *Porcellia*. In *Cyrtolites* the whirls do not touch, and in *Ecculiomphalus* they are drawn out like *Spirula*.

Family Firolidæ. (*Glass-Argonauts.*)

It is no wonder that the shell of *Carinaria* has been taken for an Argonaut; and even that the true animal of the Argonaut was thought to be allied to this, which may be considered as the typical Heteropod. The front part of the gelatinous body is enormously developed, while the abdomen is small, and the tail (which takes the place of the opercular arm of the *Atlants*) is short and pointed. There is a long snout; with a short tongue, toothed as in the Strombs and Helmets. The eyes are hour-glass shaped, highly organized, and often furnished with a little eyelid. They float upside down, with their foot at the top, in the shape of a flat fin, armed with a small sucker for adhesion. Below, the principal viscera hang out from the back, and are protected by the glassy shell, the gills projecting beyond it. They come up to the surface to feed in the evenings, and are found in most warm seas. *Cardiapoda* has a discoidal shell, with flaps round the mouth. In *Firola*, there is no shell to protect the nucleus; and in *Firoloidea*, the gills are on the tail, and there is no sucker on the fin.

Family Phylliroidæ.

This family may be considered either as degraded Heteropods or Nudibranchs, forming an exact transition between the two. They

have no gills or fins; being simply a floating, gelatinous, slug-like body, with long tentacles but no eyes. In the union of sexes, the teeth, and the digestive organs, they resemble the Nudibranchs; in their habits and general appearance the Heteropods. They breathe all over the skin, like the lower species of *Firoloidea*. The tail of *Phylliroë* is flattened into a fin; that of *Acura* is pointed.

Family PTEROSOMATIDÆ.

The curious little bit of jelly which composes this family may be compared to a thin *Acura*, with eyes instead of tentacles, but no snout; laid on the middle of a broad, floating flap. Its anatomy is not yet made out; but it forms a transition to the Pteropods.

CLASS PTEROPODA.

(*Wing-footed Mollusks.*)

The "Sea-Butterflies," as they are sometimes called, are a race of creatures formed to live, permanently, swimming about in mid ocean. They are recognized at once by the two delicate fins, which are constantly moving, with considerable animation, when at the surface of the water. Most of them are crepuscular or nocturnal in their habits; spending the day, poised in the lower depths, and rising, at different periods and degrees of darkness, according to the species, to enjoy their active life. Some kinds, however, disport themselves beneath the mid-day tropical sun. In their first stage, they exactly resemble the fry of the Gasteropods; but the larval fins of the Pteropods fall off, like those of their neighbors, and the permanent fins are developed round the neck, answering perhaps to the neck-lappets of the *Turbos*, &c. They have no foot; but in some of the groups there is a little lobe between the fins, which is its commencement. Sometimes their feelers have a few minute suckers, by which they can hold their prey or moor themselves to floating objects; in which, and in the bending back of the alimentary canal along the abdomen, they resemble the Cephalopods. They are however inferior, in point of organization, to the Crawlers. They have a very feeble circulation and respiration; the nervous centres are behind the gullet; there are no eyes; the gills either do not exist or are near the tail; and the senses are rather diffused over the body than localized in special organs. In the reproductive system, and in many special points of structure, they closely resemble the Heteropods. In fact, it is probable that the whole class of Pteropods should be regarded simply as a subclass of Gasteropods, connected with the typical forms by *Carinaria* and *Ianthina*. Like the Heteropods and Opisthobranchs, some have shells and others none; but in this tribe, the shelly races are the lowest in rank, inasmuch as they have no heads: in this respect alone passing into the next great group of bivalves. They are, therefore, here arranged after the naked tribes.

The Pteropods are few in number, as far as species are concerned; but these are widely diffused, may of them being common to the Atlantic and Pacific oceans. But in individuals they are incredibly

numerous; their tiny, fragile, transparent forms being found in vast shoals, so filling the sea, that even in the Arctic regions the water is often discolored by them. They never willingly approach the shore, not having the muscular power of the Cephalopods to swim away from danger: but their delicate glassy shells line the sea bottom at enormous depths, and in many districts will form almost the only fossils by which future geologists will recognize the strata. The living forms of Pteropods are all very small, the largest scarcely reaching two inches in length. They first appear in the Eocene beds. There are, however, certain puzzling shells, found in the palæozoic rocks, which may have belonged to gigantic animals of the tribe.

Order I. GYMNOSOMATA. (*Naked Pteropods.*)

These creatures have no mantle or shell, and the gills are indistinct. They have however a respectable head, and a tongue-ribbon of numerous rows of hooked teeth, as in the Opisthobranchs. Like all the other Pteropods, they are carnivorous, preying on minute Crustaceans, Jelly Fish, or Infusoria.

Family Pneumodermonidæ.

The *Pneumodermons* have the body shaped something like a Cuttle-fish, and highly colored. There are two tentacles, copiously fringed with tiny anther-like suckers. The gills are leaf-like projections at the tail. When touched, they fold their wings round their neck, roll themselves into a ball, and fall to the bottom. In *Spongiobranchia*, the gills form a spongy ring round the tail; and the tentacles have cup-shaped suckers, forming a close approach to those of the Cuttles. In *Trichocyclus*, there are no gills; but three rows of tiny hairs round the head, tail, and middle take their place.

Family Cliidæ.

Clio was the name given by Linnæus to all the Pteropods then known. It is now restricted to rather slender animals which, small and delicate as they are, form the principal food of the mighty whale. The monstrous creature opens his enormous mouth; takes in a sea of water; filters out his *Clios* through the whalebone sieve; and ejects the water through his nose. The *Clios* have a number of small tentacular processes round the mouth, furnished with minute suckers. In swimming, it touches the ends of its fins on each side. In *Cliodita* the tentacles are obsolete. In *Pelagia* the head (to speak respectfully of this indistinct organ) is truncated in front.

Family Cymodoceidæ.

Cymodocea differs from other Pteropods in having a second pair of club-shaped wings, behind the ordinary ones.

Order II. THECOSOMATA. (*Clothed Pteropods.*)

In these headless tribes, the body is generally shortened, and inclosed in a glassy, horny, or cartilaginous shell.

Family HYALÆIDÆ.

The *Hyalæas* are protected by a globular shell, consisting of a dorsal and ventral plate, (as in the Palliobranchs,) united at the tail. The two fins are retractile into the shell, and unite round the mouth. There are two tentacular processes behind, passing through side-slits in the shell, showing a resemblance to *Cymodocea*. In *Diacria* these processes are very small and inclosed, while the tail is produced. *Cleodora* has a glassy, pyramidal shell, of three flat sides, each ending in a spike. In *Balantium* the shell is funnel-shaped, not spiked. *Creseis* has a very slender, pointed, circular funnel. In *Cuvieria*, the shell is swollen at the base like an urn, generally with the point truncated. The point remains permanent inthe *Vaginella* of the Bordeaux beds.

Family CONULARIADÆ.

The great carboniferous fossil *Conularia* was probably nearly related to *Cleodora* and *Creseis*, but as its relations are not clear, it is kept in a separate family. The shell is four-sided, and very beautifully striated across. In the Devonian form *Coleoprion*, the angles are rounded-off. The Silurian *Theca* has a shell like an elongated *Cleodora*, without spikes. *Pterotheca* has wing-like projections at the sides.

Family LIMACINIDÆ. (*Spiral Pteropods.*)

The tiny shells of *Spirialis* are spiral, with the point either raised or depressed. Between the fins is the rudiment of a foot bearing an operculum. These creatures furnish the nearest approach to the larval Gasteropods. In *Limacina* the mouth is round, and there is no operculum. The shells of this family may be known from the Macgillivrayids, by being always reversed.

Family CYMBULIADÆ. (*Glass-Slippers.*)

The lovely *Cymbulia* inhabits an elegantly-cut cartilaginous shell, foreshadowing the Argonaut, the wings flapping on each side, as the sails of that Cuttle were formerly supposed to act. The lingual teeth in this genus, and in *Eurybia*, (which has a cup-shaped boat, and tentacles,) are arranged in three series. *Eurybia* similarly foreshadows *Bursatella* among the Opisthobranchs. *Tiedemannia* is like a *Cymbulia* without the glass-slipper, forming a transition to the first order; while the delicate little *Psyche* seems no more than a minute, transparent globe, wafted over the banks of Newfoundland by its spreading wings. And so end the higher groups of Molluscous Animals.

CLASS LAMELLIBRANCHIATA,

(or *Plate-gilled Bivalves.*)

The remaining classes of mollusks present us with a very different type of organization; inferior, indeed, to the head-bearing tribes, and

yet equally perfect after its kind. The student of vertebrated animals and of the various insect tribes, as well as of the Cephalopod and Gasteropod mollusks, naturally looks upon the head as the most important part of every living creature. We are now going to be introduced to animals in which not only the head becomes sometimes obsolete, as in the shell-cased Pteropods, but the whole plan of the organization makes the existence of a head useless, and therefore impossible. The special work appointed for the bivalve and cloaked mollusks in the economy of nature, is to filter the water at the sea bottom from its infusorial particles. They never *prey*, either upon living creatures or sea plants; hence eyes, jaws, snout, and curiously-armed tongue, which are the characteristics of ordinary mollusks, would be entirely useless. To go about looking for food, when the very air they breathe comes burdened with dainty meat, would be a waste of energies; so that a swimming or crawling foot is not a requisite of their life. Their special functions are to digest and breathe, in a quiet but uninterrupted manner. All the locomotion they require is to settle themselves in a snug place; and then they simply suck-in the water, and let it bring food to their mouth and air to their blood. When at rest, they are entirely encased in their shelly covering, like the *Turbo* and *Nerite;* but when in action, instead of crawling out of their shell, they open the shell itself to let in water. The shell is therefore made of two plates; which in the ordinary bivalves interlock by means of a toothed hinge, and are fastened together by a ligament.

The headless tribes of mollusks naturally divide themselves into three great divisions. In the clams, oysters, mussels, and cockles, the animal breathes by means of large plate-shaped gills; and the valves are, as it were, great wings on each side of the body. But in the lamp-shells, there are no gills, the breathing being performed by the skin, and by the action of very delicate hairs arranged on twisted feelers; and the shelly valves, instead of being side-wings, are shields on the front and back of the animal. In the third division, instead of a shell, the animal is wrapped up in a leathery coat. The ordinary bivalves are often called *Acephala* (Headless creatures;) a name which is equally applicable to all three divisions, and to part of the Pteropods. Their common name is *Conchifera* (Conch-bearers;) but as conchs are univalve shells, and as the name was given to include both the clams and the lamp-shells, it appears best to distinguish them by their leading characteristics as *Plate-gilled, Mantle-gilled, Cloaked* mollusks.

The oyster tribe lie on one side; and have neither foot nor breathing pipes. But ordinary bivalves do not lie as their shells are seen in cabinets. They stand upright, like a crawling Cuttle Fish. Their foot, or digger, is at the bottom; their nose and vent pipes close together at the top. At the back are the digestive organs: in front, a large water chamber, with the gills above, and the mouth below, behind the foot. The mantle enfolds the whole body, and secretes the two shelly plates. These assume an approach to a spiral form, from the growth being in front, the ligament remaining fixed. The breathing pipe is not a mere gutter, as in the predacious univalves, but a fleshy tube, armed with muscles to suck in the water, and often ele-

gantly fringed with feelers to aid the currents. As the water is sucked into the gill-chamber, the plates collect the minute plants and animals that float in it. These lie in their grooves, and are gradually formed into threads, which are carried down towards the mouth. Here they are laid hold of by a pair of long delicate flaps or lips, which draw the threads to the mouth. The filtered and carbonized water is forced back, along with the fœcal matter, through the excurrent pipe, which is generally longer than the other, in order not to interfere with the purity of the inhaled current. These mollusks generally live covered up with sand or mud; and might escape detection, but for the slight protrusion of their pipes; yet the disturbance they make in the water by their vigorous breathing is well known to all keepers of aquariums.

The bivalve shells are objects of great beauty, both as respects form, sculpture, and color. It is however unfortunate for geological purposes that the principal differences among them depend on the internal structure, the hinge teeth, the muscular impressions, and the marks of the siphon pipes, which cannot often be seen in fossil specimens. Dr. W. B. Carpenter has however shown, (*v.* Reports of the British Association, 1844, pp. 1–24,) that the structure of the shell affords very characteristic marks in several of the families and genera, by which the affinities of fossil specimens and even fragments may often be satisfactorily determined.

The bivalves do not group themselves into natural orders like the univalve mollusks. There is a much greater similarity of type among them, and the points of difference are not constant among the creatures whose general relationships correspond. If we compare a "clam" with an oyster, we see at once that the clam has two water pipes, a foot, and the mantle closed in front; while the oyster has an open mantle, without foot or pipes, and has only one muscle instead of two to work the valves. Yet if we separate according to any one of these characters, the division, will not suit others, and we shall be obliged to part closely allied groups. It may be best therefore to allow the families to follow each other in a natural order, without insisting on orderly or suborderly lines of demarcation. The following are however the leading types of structure:

I. *Borers, Razor-shells, Mya-clams*, &c., in which there are two long water pipes, more or less united and retractile, the gills being produced into the breathing pipe, and the mantle closed except for the foot and pipes.

II. *Venus-clams, Tellens, Cockles*, &c., in which the pipes are generally separate, the gills not produced, and the foot mostly flattened for crawling or leaping.

III. *Sea and Freshwater Mussels*, &c., in which the mantle-lobes are only closed to form a breathing hole.

IV. *Oysters, Fan-shells* and *Arks*, in which the mantle-sides are entirely separate.

The *Venus* tribe may be considered as the typical and most highly-organized Lamellibranchs; from these the stream of affinities flows down through the Mussels and Oysters, towards the Palliobranchs; and through the Borers towards the Tunicaries. As however we can-

not speak or write in diverging lines, it is more convenient to begin with the borers, although they are in many ways abnormal.

Several of the Lamellibranchs are now known to have the sexes separate, like the trunk-bearing univalves. As the individuals always maintain a solitary existence, it is probable that the fecundating influences are diffused and inhaled through the breathing currents. The eggs are matured between the outer plates of the gills. The young always swim freely about, by means of a hairy flap, which disappears when the foot is developed, at the front of which is a slender tail. At this time they have minute eyes, which disappear as the animal hides itself within its wings. It is singular that in the last published treatise, these creatures are said to be self-impregnating hermaphrodites; although the difference of shape between the shells of male and female specimens has often raised them to the rank of different species.

It is evident from the essential conditions of life in these headless mollusks, that their structure could not be modified to exist on land, like the Pectinibranchiate and Pulmonic Snails. A very few of the plate-gilled families are able to exist in fresh waters; but the whole of the other classes are marine.

Family Pholadidæ. (*Piddocks* or *Date-Fish.*)

If we divide the ordinary bivalves into active or sedentary, according to their habits of life, we shall find among the latter the two most widely divergent groups—the *oysters*, which sleep on their sides, and the *borers*, which stand on their feet. The habits of the borers have been already described at some length, (*v.* Smithsonian Report for 1859, pp. 209–217:) it will be sufficient here to point out the principal differences of structure. The Piddocks have white shells; generally very thin, but strong, and adorned with rasp-like sculpture. As this sculpture however is for the most part turned towards the aperture, it cannot be much used for excavating the hollows. The naturalist who took the trouble to bore a hole with the shell, could do so most easily if he turned the shell the wrong way in. As before stated, the stout club-shaped foot is probably the principal instrument of abrasion. This is fixed by strong muscles to the shell, which has no articulated hinge and ligament, like other bivalves, but is strengthened by a spoon-shaped process, curling up from within the beaks. The pipes are long, united till near the ends, and inclosed in a tough skin which is often protected by cartilaginous "cups." The shells gape all round, except at a point before and behind, and the vacant spaces are generally covered, in the adult, by accessory plates; which caused Linnæus to separate them from their allies as being "multivalves." They are phosphorescent, living by their own light; and are often eaten as a delicacy. *Pholas* proper has one shield placed behind the hinge. *Dactylina* has a shield over each valve, a cross piece, and a long plate along the back. *Zirphœa* has a broader shell without plates: it is the only one of the British species which is also found in America. The little group *Navea* are slightly modified to suit their residence in sponge. *Xylophaga* looks like a very short Ship-worm, making bur-

rows in floating wood, against the grain, about an inch long. The body is globular, with narrow pipes, separated at the end.

In the "Cup-pholas" tribe, the foot opening is large in the young shell, but closed in by shelly matter in the adult. There are however transition forms. *Pholadidea* has a single large cup in the adult, but no accessory plates. In the African *Talona*, there are two small cross-plates; and the foot-gape is very small, both in the young and adult. *Martesia* burrows in floating wood, and has the valves divided into two areas, like *Pholadidea;* it differs in having a large shield over the beaks, with another along the back; and in having no cup. One species has been found living in a Borneo river, twelve miles from the sea. The curious west American genus *Parapholas* has the valves divided into three areas, the third consisting of a tiled row of cup-plates. The adult is encased in large accessory plates, in front as well as behind. In this group the foot-gape in the adolescent animal is guarded by a strong deposit of shelly matter, to prop up and aid the foot. *Jouannetia* is like an exaggerated *Parapholas*, in which the callous plate of one valve overlaps the other, and the tile-cups are almost obsolete. As in the other members of this section, the pipe-ends are joined and surrounded by a common fringe, accounting for the roundness of the burrow-mouths. The Cup-pholads are found fossil in the secondary rocks; the ordinary forms in the tertiary strata.

Family Teredidæ. (*Ship-Worms.*)

The Ship-worms are simply Pholads enormously lengthened; although at first sight the shape of their body would cause them to be regarded as Annelids or Vermetids, rather than bivalve mollusks. The common *Teredo* has a body from one to two and a half feet long; *i. e.* including the pipes; but the body, strictly so called, which contains the principal viscera, and is enclosed in a bivalve shell, open at each end like a pair of pincers, is not larger than a pea. The gills are long and extend into the tube, which is protected by a coat of shell outside. At the outer end, where the pipes divide, there are a pair of shelly flaps, which aid in working the inhalent and excurrent siphons. These flaps, which look like the "screw"-plates of a steamer, might be mistaken for the boring apparatus, but that they are always found at the opposite end from the boring foot. This is finger-shaped, as in *Gashochæna;* but it is quite equal to the task of wood-boring. There is no mollusk except the Ship-worm, which has excited the fears of merchants and statesmen. Not only ships, (if not coated with metal or kyanized,) but piles and dock gates, have fallen victims to its ravages. Nevertheless it is a very serviceable creature, gradually destroying wrecks and other submerged wood, which might otherwise block up harbors and impede navigation. They are ovoviviparous and very prolific. They always bore *with* the grain, only turning aside to avoid knots or neighborly intrusion. In *Xylotrya* the breathing flaps are pen-shaped and jointed. Some of the species are found boring in the floating husks of cocoanuts.

There is a curious group of Sand-worms, as yet very little understood, but closely related to the Ship-worms. They encase themselves

in very thick shelly tubes, often a yard long and two inches across, of prismatic structure like the *Pinnas* and *Belemnites*. At the outer end, the pipe is divided across for a considerable distance. It is said that these *Septarias* have no bivalve shells at all; but that the foot-end is closed in by a cleft shelly plate.

The Ship-worms are connected with the ordinary borers of the fossil genus *Teredina;* in which the animal is as short as a stretched-out *Pholas*, enclosed in a thick tube, somewhat divided at the outer end. The valves, which were probably free in the young state, are soldered into the tube in the adult, so that the animal was completely encased. Fossil Ship-worms are found in fossil wood as far back as the Lias.

Family Gastrochænidæ. (*Tube-Shells.*)

The valves of *Gastrochœna* have a true ligament, and move freely in their burrow, so that the little finger-like foot which protrudes from the otherwise closed mantle, is able to perform as much abrasion as the stout organ of the *Pholads*. When the *Gastrochœna* does not burrow in solid stone or shell, it forms an irregular club-shaped tube, in which it encloses both its pipes and its valves. In *Chœna*, which burrows in sand, the tube is straight; and the part which contains the rectangular valves is partitioned off from the pipe portion. The very curious shells of *Bryopa* are like a *Teredina* with one valve loose, and the other cemented into the tube. The animal is stumpy and irregular, with rather short fringed pipes, and has the general aspect of a tunicary in a shelly case. It is difficult to understand the use of the single loose, and the single fixed valve: Dr. Darwin might regard it as a *Gastrochœna* passing into a *Teredina*, or *vice versa*. The fossil genus *Clavagella* differs only in having the closed pedal end surrounded with a bunch of short tubes, in which respect it forms an interesting passage to the Watering-pots or *Aspergillum* group.

At first sight a "Watering-pot shell" would not be supposed to have any connection with ordinary bivalves. It consists of a tube, open at one end, at the other closed by a disk, full of holes, and generally surrounded by frills of shelly tubes. On looking attentively near the *rose* however, we shall see two irregularly imbedded valves, which are small *in Aspergillum* (the principal part being free inside) and large in *Penicillus*, and which show the intimate relation of the creature to *Clavagella*, *Chœna*, &c. In the middle of the rose is often a slight chink for the rudimentary foot. The open end, which appears above the sand, and is often adorned with one or more ruffles, affords an orifice for the breathing pipes. In *Foegia* the valves can scarcely be seen outside. The animal of *Humphreyia* attaches itself when young by the front edges of the valves, which it gradually extends into a tube.

Family Saxicavidæ.

The *Sax cava* group are like shortened Gastrochænids, without any shelly tube. They sometimes bore, but more often nestle in holes made by other creatures, or in corners of rocks and roots, mooring themselves

by a lyssus, which they spin by their small grooved foot. It is said that five genera (placed in different families) and fifteen species have been made out of different conditions of the *Saxicava arctica*, which has spread itself over the northern hemisphere from the time of the middle tertiaries, having attained its greatest development in the drift period. The *Cyrtodaria* of Newfoundland is one of the coarsest of shells, covered with a horny skin, which in drying often cracks the shell inside. *Glycimeris* has a shell exactly like *Panopæa;* but the animal is a gigantic *Saxicavid.* The long pipes are united almost to their ends, the gills protruding into them; and the mantle-line in the shell is broken into joints. The shells gape all round like *Pholas*, but have a strong external ligament fixed to stout fulcrums.

Family Myidæ. (*Gapers.*)

In the *Myas* (called "Clams" in New England, and brought to market for food,) the shell is tolerably regular, and covered with a wrinkled skin which is produced over the pipes. These are united, and fringed at the end. The species are widely diffused, in time and space, and are generally pretty large. The cartilage is fixed in a pit between a projecting spoon-shaped tooth in the larger valve, and a hollow in the smaller. The Californian *Platyodon* has the pipe-ends strengthened by four shelly valves, reminding us of *Teredo.* The name *Mya* was given by Linnæus to all shells with an internal cartilage; but the character is not always constant in the same family. *Panapœa* (to which and to *Pholadomya* most of the fossils called "*Mya*" belong) has an external ligament, and small interlocking hinge-teeth, like *Glycimeris. Lutraria* has a shell resembling the New England "clam," but of more porcellanous texture; and with a spoon-shaped process in each valve to support the cartilage by the side of a tooth. Several shells generally associated with it by American authors have a *Mactroid* animal. The great Californian *Tresus*, which is eaten at Puget Sound, has small teeth on each side of the cartilage pit. *Seizocheilus* may prove to be identical with *Tresus;* it has two horny valves at the end to protect the pipes. The animal of *Eastonia* has not been examined; but the shell is like a heavy, swollen *Latraria*, with radiating furrows outside.

Family Corbulidæ. (*Basket-Shells.*)

The *Corbula* group are like little *Myas*, but they scarcely gape, and have very short pipes, fringed at the ends. The foot is finger-like, adapted to poke in mud and sand, where they live often in immense profusion. They have one valve much smaller than the other; the hinge consisting of a conical tooth by the side of a cartilage pit in each valve. *Potamomya* includes the flattened estuary species; and *Corbulomya* some of the fossil forms, which begin to appear in the oolites. *Sphœnia* has the nestling habits of *Saxicava*, with the front end of the shell very short. *Cryptomya* has a Myoid hinge, with a shell intermediate between that and *Sphœnia.*

Family ANATINIDÆ. (*Lantern-Shells.*)

The shells in this family are almost always thin, pearly within, and roughened outside. They have an internal cartilage, supported on a spoon-shaped plate at the hinge, and strengthened by a shelly "ossicle" within. *Anatina* has the spoon supported by a clavicle at the umbos. The oolitic fossils, *Cercomya*, have the valves concentrically furrowed. In the nestling *Tyleria*, (of which only one specimen is known from Mazatlan, the clavicle is loose, twisted round the side of the shell, and united to it by numerous bridges. *Periploma* has a rectangular shaped body, without clavicle. *Lyonsia* has a shell of irregular growth, like *Saxicava;* and a very small spoon close to the umbo. Its Californian neighbor, *Mytilimeria*, lives imbedded in the nests of Tunicaries, and can scarcely open either its valves or its mantle. The beaks of the shell are spirally twisted, as in *Isocardia*. The shells of *Thracia* are not pearly, and are very rough outside. Some of the species are nestlers and distorted like *Lyonsia*.

The very beautiful shells of *Neœra* are shaped like a *Corbula*, with produced beak to shelter the delicately fringed pipes. They are thin and pearly, and only found in deep water. *Theora* lives in shallower water, is more compressed, and has a very wide mantle-bend like the Tellens. *Thetis* has very short siphons, and a very long tubular foot; the hinge resembles the Kelliads.

Two singular groups are placed here provisionally, until the animals have been examined. The African *Tugonia* (also found fossil in the Pliocene) has a globular, twisted shell, somewhat resembling *Neœra*, with a very large spoon-shaped cartilage-pit, and a very small mantle-bend. *Anatinella* is shaped somewhat like *Myodora;* with very long, narrow cartilage pits, and no bend in the mantle line. In this respect it resembles many of the *Corbulids*.

Family PHOLADOMYIDÆ.

There is only one living representative (from the West Indies) of a large tribe of puzzling fossils, which have received various names without much being known of their affinities. The living animal agrees with Anatinids in having only one gill on each side, but differs from all its predecessors in the mantle having a fourth opening in front. The ligament is external. The principal fossil forms which used to be classed under the general names of *Pholadomya* and *Amphidesma*, *Elnio*, &c., have been separated as *Homomya*, with thick shell and concentric sculpture; *Myacites* with *Goniomya*, *Tellinomya*, *Grammysia* and *Sedgewickia;* *Ceromya*, *Gresslya*, *Cardiomorpha* and *Edmondia*.

Family MYOCHAMIDÆ.

This is a small group of attached shells, representing as it were the oysters and *Chamas* among the Anatinids. The animals have strong points of resemblance with *Pholadomya*, having a minute ventral opening. The ligament is internal, and has an ossicle as in *Anatina*. *Myochama* lives on other shells at great depths, and has a small mantle-

bend. *Chamostrea* is shaped like *Chama*, attached on the anterior side, without sinus. They are all peculiar to the Australian region.

Family PANDORIDÆ.

The *Pandora* group are also nearly related to the Anatinids. The shell is shaped like the more regular of the *Lyonsias*, but flattened, especially on the right valve. The hinge is V-shaped, like *Placuna*, with an internal cartilage, but no ossicle. The valves are pearly within, and with minute prismatic cells outside, of which two hundred and fifty are about as large as one in *Pinna*. The mantle line is broken as in *Saxicava*, and scarcely bent, the pipes being very short, separate at the end and fringed. *Myodora* wants the V-shaped hinge, and has an ossicle. It is peculiar to the East Indies.

Family SOLENIDÆ. (*Razor-Shells.*)

We pass on to a very different-looking race of animals, though agreeing in many essential respects with those that have gone before. The Razor-Fish have the same habit as the *Myas*, *Panopœas*, &c., of burrowing in the sand; only they are created for more rapid movements. About two-thirds of the animal consists of the powerful foot, which can be pointed out, or made club-shaped, for the varied necessities of sand-boring, which it accomplishes with such rapidity that the creatures are difficult to catch, burying themselves to a great depth when disturbed. The pipes are very short, and not extended beyond the shell. This is like a piece of pipe cut across lengthways. The *Solen* may be taken as a good illustration of the ordinary habits of life of bivalves. It stands on its foot, like other animals; but this is the *anterior* or *fore*-end of the shell, the mouth and lips being behind it. The top of the animal is at the *posterior* or *hinder*-end of the shell; while the hinge is at the back, and the opening of the valves at the front of the creature, the shells being the side-wings. The length of the shell is from the anterior to the posterior ends, which represents the *height* of the animal. The *breadth* is from back to front of the animal; while the *height*, or thickness of the closed valves, really represents the *breadth* of the living creature. *Solen* proper has a straight shell, and one tooth in each valve; while *Ensatella* has a curved shell and 2–3 hinge teeth.

Family SOLECURTIDÆ. (*Short Razor-Fish.*)

The shells of this group are intermediate between the true *Solens* and the Tellens. The beaks, instead of being at the bottom end, are more or less near the middle, and the valves are generally flattened. The pipes are separate at the end, and more or less retractile. *Solecurtus* proper is like a Razor-shell cut short, while the animal is almost as long; the pipes being united into a stumpy tube till near the end. *Novaculina* contains the species which live in brackish water, and are covered with a coarse skin. The intermediate species have been called *Tagelus*. In *Cultellus*, the shell is flattened and the beaks are strengthened by a small slanting rib. The pipes are short and separate. *Ma-*

chœra has a stout rib coming out at right angles from the beaks. The mantle of the animal is beautifully fringed, and the pipes rather long. The animal of the European *Ceratisolen* is very similar; while the flat narrow shell is drawn out nearly to the length of a *Solen*. All the shells of this family gape, both at the foot and pipe ends; and their habits are like those of the Razor-fish. They do not make their appearance on our globe till the cretaceous age: the true *Solens* not till the tertiaries.

We now come to the typical Lamellibranchs, in which the pipes are narrow in proportion to the animal, not swollen to allow of the entrance of the gills. They are more or less united, or prolonged, in the various families and genera; passing from the Tellens in some of which they can be stretched out much longer than the shell, and widely divergent, to the cockles in which they are united together, and scarcely project beyond the valves.

Family Tellinidæ. (*Tellens.*)

The Tellens form a very beautiful and extensive family, abounding on all shores, where they live in sand or mud, generally at slight depths. The animals have very long, slender, and divergent pipes, and large triangular lips. The mantle is elegantly fringed, and open in front for the tongue-shaped foot. The shell is generally thin and transverse, often highly colored and very delicately sculptured.

In the first group, the shell gapes and forms a transition to the short *Solens*. The shells of *Soletellina* are generally violet, with a somewhat horny epidermis; having small hinge-teeth, and beaked at the breathing end. There is a strong ligament, supported on stout fulcrums. In *Sanguinolaria*, the shell is shortened and very thin. *Psammobia* gapes but little, and generally has the hinder side angular. In *Capsula* the shell is swollen, and ornamented with radiating ribs. This group makes its appearance in the cretaceous age.

The typical group *Tellina* consists of shells varying from a very transverse to a nearly rounded form, not gaping, and with a slight fold or angle at the breathing end. The muscular impressions are rounded and polished; and the mantle-bend is very large, occupying a large proportion of the shell. In the Californian species, *T. nasuta*, it is larger in one valve than in the other. The side teeth of the hinge appear to be of very little consequence in this group, being sometimes present in both valves, sometimes only in one, and often altogether absent. About two hundred species are now living, and nearly a hundred and fifty are found fossil, beginning with the oolites. The orbicular species have been called *Arcopagia*, a name also used unfortunately for a group allied to *Donax*. Some of the British, and probably of the American species are said to have only two, instead of four gills: they have been named *Macoma*. The *Strigilla* group, which abound in tropical America, have rounded shells with the valves obliquely sculptured. The elegant shells of *Tellidora* are found on the east and west coasts of tropical North America; they are white, flat, and triangular, like *Myodora*. The shells of *Gastrana* are some-

what wedge-shaped, with a bipid tooth in one valve. The animal is of sedentary habits, boring in mud or clay. The shell of *Elizia* is very like a flat *Diplodonta*, but there is a wide mantle-bend. *Lucinopsis* has a swollen thin shell, with a hinge like a *Venus;* but the animal is of the Tellen type.

The next group have the cartilage internal, like the *Mactras;* which appears at first sight a very great distinction, but there are some species that might be ranged with equal propriety in either section, the cartilage-pit being at the margin, close to the ligament, which is always external and generally slender. *Scrobicularia* lives buried in estuary mud, extending its pipes five or six times the length of the shell. The hinge-teeth are very small. *Semele* has a stronger shell, with a tooth on each side of the cartilage-pit. *Syndosmya* has a very thin, white, Tellinoid shell; with a hinge like *Scrobicularia*, but with lateral teeth. The animal of *Cumingia* is irregular, the shell being found nestling in crypts like *Saxicava*. One valve has very strong lateral teeth; the other none.

Family Donacidæ. (*Wedge-Shells.*)

The *Donax* family differ from the Tellens in having shorter breathing pipes, and stout, triangular shells. In the typical species of *Donax*, the breathing-end is very short, the foot-end long and pointed. The valves are stout, with crenulated margins and short ligament. There are strong lateral teeth. *Heterodonax* wants the crenulations, and has a rounded form. *Iphigenia* has a somewhat swollen shell, without lateral teeth. It lives in estuaries, and the species greatly resemble each other. The curious genus *Galatea* is peculiar to the African rivers. It has a very thick, triangular shell, with stout hinge-teeth like the *Venus* tribe.

Almost every sandy shore in the warmer regions has its species of *Donax*, which lives in myriads at a certain depth below the surface. At Panama, the natives clear off the sand just below this depth, and thus quickly collect bushels of the mollusks, which are considered dainty food. Yet the species, though more abundant than any other bivalves, are less widely distributed than most, each district having its peculiar form. They have not been found fossil previously to the tertiary ages. As among the Tellens, so here, a group is found with an internal cartilage. The marine *Erycina** has no little external resemblance to *Galatea*, being triangular and solid; but the cartilage is in a narrow pit between stout teeth. *Mesodesma*, which abounds in the Australian region, is shaped like Psammobia, but solid; with two short, stout lateral teeth. *Donacilla* has a wider distribution, and is wedge-shaped, with one of the lateral teeth long. *Ceronia*, one species of which inhabits the New England seas, has the side teeth strongly grooved. The Messrs. Adams unfortunately assign all the

*The genus *Erycina* is here restricted to the triangular shells of the Mesodesma type, called *Paphia* by modern authors. This latter name has a very obscure and intricate genealogy, and had better be dropped, as it is in use for butterflies. The heterogeneous genus *Erycina* of Lamarck has very properly been dismembered; but the name should be kept for the principal species.

species to California; although the west coast of North America has not yet furnished a single shell belonging to this sub-family. The shells of *Anapa* are shaped like *Erycina*, but there is no mantle-bend, and the animal may prove to be allied to *Crassatella*. The shells of *Ervillia* belong to the Atlantic ocean and the Red Sea. They have a Tellinoid shape, with deep mantle-bend, but no lateral teeth. Shells of this section have been found fossil in the earlier cretaceous age.

Family Mactridæ.

The beautiful shells of this family are generally somewhat triangular, and with an internal cartilage, like *Erycina:* but the breathing-pipes are united to the end, and beautifully fringed The mantle is freely opened in front, allowing free play to the tongue-shaped foot, which is used either for burrowing in sand or for leaping. The lips are very long and pointed. The shells are generally thin, and often highly colored. *Mactra* proper has well developed lateral teeth, double in one valve, and a small ligament separated from the cartilage. *Spisula* has the side teeth strong and cross-ribbed, as in *Ceronia*. The American genus *Mulinia* has the ligament internal as well as the cartilage; the side teeth smooth, and the mantle-bend angulated. In the African form *Schizodesma*, there is a triangular opening between the beaks to receive the ligament. *Mactrella* is a tropical American group; with very thin shells, keeled on one side and gaping at each end. The side teeth are very short, and the mantle-bend large and round. *Harvella* is another tropical American form, with paper-like shells, keeled on one side and concentrically furrowed. The ligament is separated from the cartilage. In *Standella* it is joined to the cartilage, as in *Spisula*, and the side teeth are short, not projecting beyond the cartilage pit.* All the strictly marine Mactrids have a V-shaped hinge tooth, more or less developed. They are found fossil in all strata from the Lias. Another tropical American group, *Rangia*, (better known as *Gnathodon*,) inhabits brackish water, and has the breathing-pipes partly separated. Though the shell is angular, the hinge line is rounded, and the V-shaped tooth is broken into two. Though the shells are so abundant near New Orleans and Mobile as to be used for making roads, they are still sadly too rare in Europe.

Another somewhat aberrant group may, from the shells alone, be grouped either with the *Lutrarias* or *Mactras*. Their true position cannot yet be determined, through our ignorance of the animals. The *Raeta*, so abundant in South Carolina, but rare in Europe is like *Harvella*, with the side teeth changed into clavicles supporting the hinge plate. *Cypricia* (unfortunately confounded by Messrs. Adams with *Cryptodon* of Conrad) is a closely related form, not furrowed, and largely gaping in front. The mantle-bend in both groups is more akin to *Lutraria* than to *Mactra*. In *Heterocardia* it is very large, as in the *Tellens*, and the hinge somewhat resembles *Rangia*. The shells of *Cœcella* inhabit shallow muddy bays. They have a mantle-bend like *Mactra*, with a hinge like *Lutraria*. The very singular

* This genus will probably be found more nearly related to *Lubraria*.

Vanganella has the shape and internal rib of *Machœra*, with a very projecting cartilage-pit, lying against the rib.

Family VENERIDÆ.

The *Venus*-tribe may be regarded as the types of the Lamellibranchs, presenting the greatest balance of characters. The animals have rather short pipes, fringed at the ends, and more or less united; the incurrent being the longer of the two, contrary to the usual habit. The mantle is closed in front, with a large opening for the tongue-shaped foot. They are found in all seas, generally in shallow water. They first appear in the oolitic strata, and are now at their maximum of development. The shells are strong, almost devoid of structure, very beautifully colored and sculptured, and held together by a stout, external ligament. The hinge teeth are very large, and generally divergent. As among the snails and other large families, there are so many intermediate forms between the extremes that the division into genera is a matter of great difficulty. The most elaborate classification of the species is to be found in Deshayes' British Museum Catalogue.

The shells of *Trigona* somewhat resemble *Erycina* and the Mactrids. They are triangular, with from three to six hinge teeth, and one rather long side tooth. The tertiary fossil *Gratelupia* greatly resembles it, with an additional number of small parallel posterior teeth. *Meroë* is wedge-shaped, with the margin crenulated, and the ligament in a deep-cut groove. *Cytherea* has a heavy shell, with a tooth next the ligament crenulated, and the outside tooth transverse. The mantle-bend is very slight. *Callista*, (which is the *Dione* of the British Museum Catalogue, and includes most of the species grouped together as *Cytherea* by Lamarck,) has a wide mantle-bend, the pipes being rather long, and united as in *Mactra*. The hinge teeth are 3-4, the outer being short, but transverse. *Dosinia* also has united siphons, with an angular mantle-bend. The shells are somewhat twisted spirally, with close concentric furrows, and a sharply-cut lunule. In *Cyclina*, the shell is thin, inflated, and without lunule, resembling *Lucinopsis;* but the animal closely resembles *Dosinia*. *Clementia* has a very thin shell, with a hinge resembling *Venus*, but pipes and mantle-bend like *Dosinia*.

The restricted genus *Venus* has the pipes separate and diverging; with a short angular mantle bend. The hinge-teeth are 3–3, nearly equal and spreading. The valve margins in this group are crenulated, corresponding with the fringing of the mantle. In *Chione*, (a bad name, because it does not include the old *Venus chione*, now a *Callista*,) the pipes are short and united at the base. The mantle-bend is very slight; and the teeth are 3–2, one being longer than the rest. The common *Mercenaria*, or "clam" of the Atlantic States, has the area inside the ligament coarsely furrowed. *Anomalocardia* has irregular, thick, triangular shells, with two teeth in each valve, and the mantle-bend almost obsolete. The little New England *Gemma* has the hinge of a *Venus*, the external aspect of a *Circe*, and the deep angular mantle-bend of a *Dosinia*.

The *Tapes* group have oblong, transverse shells; with narrow, com-

pressed hinge-teeth, often bifid. The animal has a long foot, grooved and often furnished with a lyssus. They are rather sedentary in their habits, hiding themselves in corners, and sometimes even burrowing in rock like the Saxicavids. The same species are however found on the same shores, either boring or free in the sand. The siphon-pipes are partly separate, and beautifully fringed; and the mantle-bend is deep. They most abound in the Old World. But on the northern shores of the Paçific is found a remarkable group, *Saxidomus*, with additional and somewhat irregular teeth, (as in *Trigona*,) a posterior gape, and no lunule.

Family PETRICOLIDÆ. (*Boring-Venus Tribe.*)

These creatures have the mantle closed in front, like the Saxicavids, with an opening for the small, pointed foot: but the pipes are short and partially united, as in the Venus tribe. They generally bore in shells or rock; but the opening is irregular, and displays the "nose-end" of the shells. *Petricola* has a shape generally resembling *Gastrana*, with coarsely moulded beaks. The teeth are 2–2, often partially absorbed by the cartilage area, which in the *Choristodon* section is somewhat internal. *Rupellaria* is *Tapes*-shaped, and is an irregular nestler, like *Saxicava* and *Cumingia:* the valves are generally prettily cancellated. *Naranio* has a rectangular shell, with divaricated sculpture outside, and bifid teeth within. All the shells in this family have a wide mantle-bend.

Family GLAUCOMYIDÆ. (*Solen-Venus Tribe.*)

The shells of *Glaucomya* are covered with a dark green skin, and are found in East Indian rivers, especially at the mouths. The hinge-teeth are small, as in the Tellens, and the shape is like a very transverse *Petricola*. There is a deep narrow mantle-bend, caused by the retraction of the very long, united pipes. The mantle is closed in front, except for the large mud-boring foot. The lips are large and sickle-shaped. *Tanysiphon* has long pipes, united nearly to the end.

In the remainder of the bivalves, (with a few abnormal exceptions,) there is no bend in the mantle-line, showing that the breathing pipes are not long and retractile. This however is not a character of ordinal importance. In the *Venus* tribe, we see the bend becoming smaller and smaller, till the passage from *Anomalocardia* to *Circe*, which has none, is scarcely sufficient for family distinction. In the following families, we sometimes find two perfect but short pipes, sometimes only one, sometimes a simple opening in the mantle. The mantle itself is either partially or wholly closed in front; or it is freely open for the passage of the water into the gill-cavity.

Family CYPRINIDÆ.

The shells of this group abound fossil from the secondary age, but very few are now living. The only living *Cyprina* has a shell like a swollen *Callista*, with a distant side tooth at the back. The little northern shell called *Circe minima* has an animal like *Cyprina*, with

very short siphons, and a mantle open in front. It has fewer hinge-teeth, and has been associated with *Gouldia*, which probably belongs, with the true *Circes*, to the Astartids.

Family ISOCARDIADÆ. (*Heart Cockles.*)

The animal of *Isocardia*, like that of *Cyprina*, has short pipes and open mantle. The shell is swollen, allowing of a very large gill-cavity; and the beaks spirally twisted, with the hinge-teeth following the curve of the margin. The foot is small, for sand burrowing. The fossil species are very numerous; but many called by this name belong to the *Pholadomya* group, and some to the *Arcas*. In the little group *Cardilia*, the ligament is fixed on an internal plate, as in some of the Lucinids.

Family CARDIADÆ. (*Cockles.*)

The Cockles abound in shallow water, in almost all sandy bays, and are extensively collected for food. On the northern shores of the Atlantic States, they are curiously rare; their place in the market being supplied by the clams. The animal has short pipes, covered with feelers; and open mantle, generally plaited at the margins. Most of the bulk of this mollusk consists of the foot, which is long and knee-shaped, doubled up into the gill-cavity when at rest, used as a leaping-pole when extended. The typical species of *Cardium* have swollen shells, with radiating ribs interlocking at the margins. The hinge teeth are small, but, with the side teeth, are deeply interlocking. The shells of *Bucardium* gape at the sides; those of *Levicardium* are smooth outside, but generally toothed at the margins; those of the boreal *Serripes* are almost edentulous. The cretaceous form *Protocardium* has the bulk of the shell concentrically furrowed, while the side has the usual radiating furrows. The *Hemicardium* group are keeled and flattened on one side; while the abnormal and very beautiful *Cardissa* group are flattened out on each side, with a hollow projecting keel. *Papyridea* is like a thin *Bucardium*, flattened in the opposite direction from *Cardissa*, and very much produced on one side.

The very aberrant Cockles of the Caspian Sea have very long pipes, not fringed, and united nearly to the ends. The foot is shaped as in *Venus*. The shells are shaped like common Cockles, but without teeth. Sometimes however there are one or two small ones. They are called *Adacna*, (with *Monodacna* and *Didacna*,) and are often arranged with the *Pholadomyas*.

Shells having a general resemblance to Cockles have been found fossil in all strata, beginning from the Upper Silurians. Several however must have had very different animals. The ancient group *Conocardium*, is like *Hemicardium* with a very long tube projecting from the truncated side, like the wing of an *Avicula*. The structure of the shell also is in cubical prisms; but the tube was probably for the protection of Adacnoid pipes, as in the *Gastrochænids*.

Family ASTARTIDÆ.

The shells of this very extensive family partake of the characters of

the Venerids, the Cyprinids, and the Cockles. The animals however differ (so far as yet known) in having no true breathing pipes, but only a fringed opening in the mantle, as in the *Unios*. The foot is tongue-shaped, and the creatures are of sedentary habits, sometimes burrowing in coral. They form one of the most extensive groups of bivalves in the secondary and older tertiary strata; but now most of the forms are extinct, and others are dying out. It is probable that some of the following genera really belong to the Cyprinids.

The first division have shells furrowed like the Cockles. *Venericardia* also resembles that group in having a bent foot for leaping; but the shape and hinge more resemble *Venus*. *Cardita* has somewhat the shape of *Rupellaria*, and has a short lateral tooth within the ligament. *Thecalia* has a curious cup inside the valves to receive the eggs. *Trapezium* has 3-3 hinge teeth, besides the lateral. *Corallliophaga* is shaped like *Lithophagus*, and is also a borer; but the hinge resembles Trapezium.

The oolitic fossil *Myoconcha* is shaped like *Modiola*, but was closely related to *Cardita*. It has a long tooth at the beaks, which is often encroached upon by the hinge-margin as in old specimens of *Cardita orbicularis*. *Hippopodium* (peculiar to the English Lias) has a very thick, irregular, toothless shell, looking like a gigantic *Saxicavid*. *Cardinia* and *Anthracosia* have *Unio*-shaped shells, abundant in the oolitic age, with a hinge more resembling the Cockles. *Pachyrisma* and *Opis* form a passage to the Heart-cockles. *Cypricardites*, *Pleurophorus*, *Megalodon*, *Goldfussia*, *Megaloma*, and *Pachydomus* are palæozoic forms, the relations of which are not yet properly ascertained.

The *Astarte* race are generally flattened shells with concentric sculpture. The fossil species abound in the oolites and tertiaries; the recent are few in number, covered with a thick, dull skin, and mostly from the boreal and north temperate zones. In the warmer seas are found small Astartoid shells with lateral teeth, called *Gouldia*. In the tropical regions of the east are found a group of shells with hinge resembling *Trigona*, but without mantle-bend. They are called *Circe*, and have a peculiar flattening at the beaks.

One group, related to the other members of this family in the animal, has the cartilage internal, as in *Semele* and *Mesodesma*. *Crassatella* has a ponderous shell with a stout hinge and short lateral teeth. It is found fossil from the cretaceous age. The shells of *Davila* are rounded and flattened, like *Felania*.

Family Chamidæ.

The Chama-tribe seems to interrupt the natural sequence of the families, presenting us with a race of irregular shells like oysters, always attached, and generally covered with spines or ridges, like the Spondyli. The shells are known by the two strong muscular impressions, and the *Unio*-shaped teeth at the hinge. The umbos are more or less twisted into a spiral, as in the Heart-cockles. The animal appears to resemble a stationary *Isocardia*, with the mantle closed in front, and very short pipes. The foot is bent, as in the Cockles, but its use is not clear. They are found only in the warmer seas, begin-

ning from the green sand. They are generally attached on one side; but the Caribbæan *Arcinella* has the valves furrowed like a Cockle, and attached by the right beak. Fossil *Chamas* are found from the green sand upwards. One very singular group, *Diceras*, from the oolite, is like an exaggerated *Arcinella*. Both of the beaks are prominent and spiral, and the muscular impressions are bounded by shelly plates, as in *Cucullaea*. In the cretaceous *Monopleura*, the attached valve is funnel-shaped, and the other flat. Another cretaceous form, *Requienia*, has the left valve so developed spirally that it has the general appearance of a *Paludina*, the other valves looking like a spiral operculum.

Family HIPPURITIDÆ.

The *Rudistes*, as Lamarck called them, are characteristic of the cretaceous age, and are far more aberrant even than *Requienia*. As there are no living shells at all resembling them, and many of the forms are only known by casts, there has been a great difference of opinion as to their true relations. They were however probably related to the *Chama* group. In Woodward's Manual, pp. 279–289, will be found an elaborate explanation and figures of their chief peculiarities. They have a general resemblance to *Monopleura*, having one very long valve, with numerous partitions as the creature advanced upwards, Chamoid teeth, a strong internal cartilage, and tubes in the outer layer of the shell. The free valve is limpet-shaped. The *Hippurites cornu-vaccinum* is twisted like a cow's horn, and sometimes more than a foot in length. In *Radiolites*, the cavity for the animal is much larger in proportion, the internal mould having been called from its shape "*Birostrites.*" *Biradiolites* has a very large ligamental groove. *Caprina* has a shape presenting an evident analogy to *Requienia*. One valve is twisted into a flat spiral, like an Ammonite, and is somewhat regularly chambered; the other valve being *Hipponyx*-shaped. *Caprinella* has the whirls separated, like *Crioceras*. They sometimes measure a yard across. *Caprotina* presents a more normally Chamoid appearance.

Family TRIDACNIDÆ. (*True Clams.*)

The American appropriation of the word "Clam" to the very dissimilar *Mya* and *Mercenaria* is somewhat perplexing, the name having been first given to the ponderous bivalves which inhabit the coral lagoons of the Pacific islands. They have a general resemblance to transverse Cockles, but differ from all other bivalves with closed mantles in having only one stout adductor muscle, like the oysters; the other being obsolete. The compact mantle has three openings; one in front, for the fresh water; one near the posterior side, armed with a tubular valve, for escape; and a very large one near the beaks, corresponding with a large gape in the shell for the finger-like foot, which is grooved to spin a stout byssus. A pair of valves of *Tridacna gigas*, measuring two feet across and weighing five hundred pounds, are used for holy water in the church of St. Sulpice in Paris. Such a mollusk may have been, when captured, more than a hundred years old. The

force with which they close the valves makes it dangerous to put the hand into the open shell. The Clam is considered good eating, and sometimes weighs twenty pounds. The beautiful *Hippopus maculatus* has no gape for the byssus: it is imported in vast numbers into Liverpool for parlor ornaments, where duly acidulated specimens can be procured at twelve cents each. These aberrant families make a digression from the main line of the Venus and Cockle group. We return now to the more normal forms.

Family Lucinidæ.

The shells of this family are either heart-shaped or flattened like *Dosinia;* but may generally be recognized by the great lengthening of the anterior muscular scar. The mantle is open in front, joined behind to form breathing passages. There is only one gill on each side, and the mouth and lips are very small. The foot is cylindrical and hollow, often twice as long as the animal. When at rest, it is doubled on itself, and hidden between the gills. Fossil forms are found even in the palæozoic rocks. *Lucina* proper has lateral and hinge teeth like the Cockles. Some specimens are obliquely sculptured like *Strigilla*, from which they are known by the mantle-line being without bend. *Codakia* has a hinge somewhat resembling *Dosinia*. *Loripes* has the ligament concealed and no lateral teeth. The animal has a long, fringed excurrent pipe. This is also found in *Cryptodon*, where the shell is thin and toothless.

Fimbria has a stout shell like a transverse Cockle, very beautifully cancellated. There are very few living species, but it abounds fossil from the Lias age. *Semicorbis* and *Sphœra* have no side teeth. *Unicardium* is almost toothless. The oolitic *Tancredia* is shaped like *Iphigenia*.

Family Diplodontidæ.

The shells in this family may generally be known by a bifid tooth at the hinge. The animals have two gills on each side, and a tubular foot. *Diplodonta* has a globular shell, and nestles in crevices. *Felania* a smooth, flat shell, living in sand. *Ungulina* has a very irregular ligament, and is said to bore. In *Scacchia*, the cartilage is internal, and the foot tongue-shaped. It forms a transition to the Kelliads. The shell of *Cyrenoida* resembles *Felania*, but the animal is figured with two united, rather long pipes, which however produce no bend in the mantel-line.

Family Kelliadæ.

The Kelliads all have thin, small shells, generally with an internal cartilage. The animal has a strap-shaped foot, with which it crawls about, or moors itself by a byssus at pleasure. They generally nestle in holes and crypts, and have been mistaken for borers. Some species have a very wide distribution. They are found fossil in the tertiaries. In *Kellia*, the ligament interrupts the hinge margin, and the mantle is produced in front into a breathing tube. In *Lasea*, the ligament lies on the thickened hinge-margin. In *Turtonia*, it is external; and in *Cyamium* partly so.

Montacuta is destitute of the anterior tube, and the shell is slanting; the cartilage occupying a pit between two strong teeth. *Pythina* has the shell narrowed in the middle, generally with slanting sculpture.

Family LEPTONIDÆ.

This group differ from the Kelliads in having the mantle produced beyond the edge of the valves, and adorned with filaments. The foot is spread out, for crawling like a Gasteropod. *Lepton* has a shell somewhat resembling *Kellia*, often minutely punctured, with diverging teeth. *Tellimya* resembles *Montacuta* in shape, but has an ossicle in the cartilage-pit, like the Anatinids. *Galeomma* resembles an arc, with a wide gape in front. It has a small cartilage-pit, without teeth, and opens its valves wide, like *Solemya*. *Scintilla* has small hinge-teeth, and gapes at the sides. *Cycladella* perhaps belongs to the same group; but has lateral teeth, a hinge-tooth parallel to the margin, and an external ligament.

Family SOLEMYADÆ.

The little group called *Solemya* appears more related to *Galeomma* than to either *Solen* or *Mya*. The shell is extremely thin, enclosed in a wide horny skin. The hinge resembles *Leptom*, with a very long cartilage-pit. The creature opens its valves very wide, and swims by dilating the end of its wide foot, which it works as we open and shut an umbrella to shake off the wet. The mantle is closed in front; and there is a tail on each side of the excurrent opening. There is only one gill on each side.

We now proceed to the freshwater families; the first of which has relations both to the Kelliads and the Venus tribe.

Family CYRENIDÆ. (*Fresh-water Cockles.*)

These creatures hatch their eggs within the mantle, but are not very prolific. Their habits may easily be observed by placing the little creatures, which may be found in any pond or ditch, in a little fresh spring water. They then drag themselves along by extending their transparent tongue-shaped feet, and protrude their short pipes. The young shells are sufficiently transparent to allow of the gills and heart being seen within. *Cyrena* has two short, separate pipes, and a strong shell, with 3–3 hinge-teeth, and smooth laterals. It is found in the English tertiaries, but is now confined to tropical regions. *Corbicula* has furrowed valves, with grooved side teeth. The shells of *Batissa* have strong hinge-teeth, with very short laterals. They are from the Pacific islands. *Velorita* has a very stout hinge, somewhat resembling *Cyprina*, with a slight siphonal fold.

The temperate regions abound in the thin shells of *Cyclas*, which has two rather long pipes, partly united; and of *Pisidium*, in which the shell is slanting, and there is only one excurrent pipe. Both *Cyclas* and *Cyrena* are found fossil as far back as the Wealden rocks.

Family UNIONIDÆ. (*Fresh-water Mussels.*)

As far as shells are concerned, this family forms the special glory of

North America, and especially of the drainage area of the Mississippi. The American Unios are the most numerous, the most remarkable, and the most beautiful that are found in any portion of the globe. There is perhaps a special reason for this provision. In no other known portion of the earth is there so large an area covered with soluble limestone. The water of the rivers, being saturated with this, would be unfit for many of its uses, were it not for the immense development of this group of heavy shells. The North American Unios may be regarded as so many water-filters, absorbing the lime from the water, and preserving it from reabsorption by their strong horny skins. The musk-rats also play an important part in this economy, being nature's great Unio-fishers. They bring them up out of the streams, and leave the shells in heaps on the banks.

The Unios are too easily accessible to most of the readers of this report to need much description. They have the flaps of the mantle entirely separate, (except between the anal and branchial regions,) not united into breathing pipes; but in the breathing region the edges are fringed. The foot is large, thick, and tongue-shaped, enabling the animal to crawl for considerable distances in case of drought. They are often found half buried in sand or mud, leaving the beaks exposed, which thus become worn away by the acids in the water. But sometimes they lie on their sides like oysters; and at others they fix their narrow breathing end upwards. In Europe they are rarely found except in rather deep water; but in America even large and heavy species will be found barely covered by water, and stemming strong currents. To resist these, the shells of *Unio* have very stout hinge-teeth, with long interlocking side teeth, inside the strong ligament. But the *Margaritana* group, which abounds most in quieter regions, is destitute of the side teeth; and the *Anodons*, which are thin and toothless, inhabit the still and comparatively soft waters of the lakes and ponds. The extreme forms of the Unionids are widely removed from each other; but between each are so many intermediate shapes that their division into genera, however necessary for the easy identification of species, is a matter of great difficulty. Prof. Agassiz has however found that there are differences in the arrangement of the gills and other organs, which are more or less coördinate with those of the shells. It is very desirable therefore that all persons who have access to living specimens should examine and report on them on the spot; or at any rate preserve a number of each species in alcohol for future investigation. It was in this family that the bisexuality of the Lamellibranchs was first placed beyond dispute. The shapes of the males and females, especially in the "*U. perplexus*" group, are so very dissimilar that no persons unacquainted with the subject would be disposed to consider them the same species. This is due to the eggs in the female filling the whole extent of the outer gill; in some instances, as has been computed, to the number of six hundred thousand at once. The fossil species present the same generic forms as the recent, and are found as far back as the Wealden rocks.

Of the *Unio* group, with distinct lateral teeth, the following forms belong to North America: *Eurinea*, *Lampsilis*, *Canthyria*, *Theliderma*, *Cunicula*, *Glebula*, *Uniomerus*, *Metaptera*, and *Plectomerus;* to South

America, *Corrugaria* and *Iridea;* to Africa, *Cœlatura;* to Asia, *Naia*, *Lanceolaria*, *Dipsas*, *Hyriopsis*, *Nodularia;* to Australia, *Hyridella*, *Parreysia*, and *Cucumaria*. The European *Mysca* has but slight peculiarities.

In the *Margaritana* group, without lateral teeth, the old pearl muscle, *M. margaritifera*, is found throughout the colder regions of both Old and New World. It used to be extensively fished in the British islands for the occasional pearls. *Complanaria*, *Alasmodonta*, *Leptodea*, and *Strophitus* are all found in North America; *Monocondylœa* and *Plagiodon* in South America; and *Monodontina* is an Asiatic form.

The *Anodons* of Europe, though very variable in form, are believed to belong to one species; but in North America the distinct forms are very numerous. The young of many Unionids are known to attach themselves by a byssus at pleasure; but in the South American *Byssodonta* this appears to be permanent. An accurate arrangement of the family, founded both on peculiarities in the animals and on geographical distribution, is still a great desideratum.

Family Mycetopidæ.

In the South American *Mycetopus*, the mantle is open except around the anal aperture; the shell resembles a toothless *Solecurtus*; and the foot is very much lengthened, ending in a hammer-shaped knob.

Family Iridinidæ.

The shells in this family closely resemble those of the Unionids; but the animals differ in having the mantle-flaps united at the side to form two short pipes. *Castalia* is like the Arciform Unios, with the hinge-teeth furrowed, as in *Corbicula*. *Hyria* has spreading wings like *Metaptera* or *Avicula*, with the teeth somewhat plaited. *Leila* can scarcely be distinguished from *Anodon* by the shell alone. These forms are peculiar to South America. In Africa are found *Pleiodon*, with the hinge line broken across into numerous teeth, like Arca; *Calliscapha*, with slight crenulations on the hinge line; *Spatha*, with a bent hinge, like *Alasmodonta;* and *Iridina*, like a very transverse *Anodon*. There are no members of this family known from the northern continents.

Family Etheriadæ. (*Fresh-water Oysters.*)

Just as the *Chamas* might be regarded as Cockles turning into oysters, the Etherids may be considered as *Anodons* making even a greater stride in the same direction. The shells of *Etheria*, which were first discovered by Bruce, being eaten in the Upper Nile, are free when young, and shaped like *Anodon;* they have then probably a foot. But when adult, they are attached and irregular, resembling an olive-green oyster with two muscular scars. There is then no foot, and the mantle is freely open. It is found in the tropical rivers of Africa and South America.

Still more remarkable is the *Mulleria* from New Granada. It begins life, free, like the *Etheria*, with two adductor muscles; but when adult

and fixed, it is found to have left both the early free valves, having fastened them on the right valve, and deposited layer upon layer over them. At the same time the adductor muscles have united so as to form only one scar. Lamarck made his primary division of the bivalves into those with two and those with one adductor muscle. This creature would have had to march from one to the other order, as he approached maturity. The entire withdrawal of the animal from one valve and manufacture of another is a complete anomaly. It is greatly to be desired that some New Granadian would watch the development of the animal.

Family Mytilidæ. (*Mussels.*)

The Mussels are easily recognized by their triangular shells, which are generally pointed at the anterior, and very much produced at the posterior side. The *Mytilus edulis* is much used for food in some parts of England, and is found widely diffused in the northern hemisphere, being taken on both sides of the Atlantic and the Californian coast. About 400,000 are eaten every year in Edinburgh alone, and enormous multitudes are collected for bait. In *Mytilus* the mantle is freely open, fringed in the breathing region like Unio; and the small foot is grooved to spin a stout byssus by which the animals attach themselves to rocks or to each other in enormous numbers. The shell of *Myrina* resembles *Alasmodon*, and was found on floating blubber.

The shell of *Modiola* is swollen near the hinge; and the mantle is partially closed into an excurrent tube. The animal spins a very fine byssus, in which it sometimes wraps itself up. *Crenella* has a swollen transverse shell, always furrowed outside and crenated within. The hind part of the mantle is produced into an excurrent tube, and it is partially closed in front. The animal spins for itself a silky nest, or burrows in the test of *Ascidians*. The shells of *Lithophagus* are finger shaped and very thin. They burrow in rocks, shells, and corals, the hole being only just large enough to receive them and not to turn round in. The outside end is generally encrusted with spongy layers, of different arrangement in different species, often produced into long beaks, but always outside the skin, and capable of being separated from the rest of the shell. These beaks sometimes interlock; but have no more to do with the burrowing than the pallets of the shipworms.

Fossil Mussels are found in all ages from the palæozoic times. Those from the old rocks have been grouped under *Modiolopsis* and *Orthonotus*.

Family Dreissinidæ. (*Closed Mussels.*)

These differ from the true Mussels, as *Iridina* does from *Anodon*. In the fresh-water *Dreissina*, which was accidentally brought on timber from Russia to London, and is now completely naturalized all over England, the mantle is closed all round, and produced into two short breathing pipes, with an opening for the byssus-spinning foot. The shell differs from the true Mussels in having a deck at the beak to support the anterior adductor muscle. The same deck is seen in the marine *Septifer*, and in the fossil genera, *Hoplomytilus* and *Myalina*.

Modiolarca has a thin shell moored to floating sea-weed, and greatly resembles *Modiolopsis* in shape. This also has the mantle-flaps united.

Leiosolenus represents *Lithophagus* in this family, from which the shell alone cannot be distinguished. It has however siphon pipes, and excavates a deep and very spacious burrow, like *Gastrochæna*.

The next group of families differ in the same way, as to the possession or absence of siphon pipes. They agree in having the foot large, bent, and deeply grooved; and in having numerous teeth at the hinge.

Family Arcadæ. (*Arks.*)

The boat-shaped Arks are easily known by their distant umbos, with straight hinge and two well-marked muscular impressions. The mantle is freely open, without pipes, and the mouth is not provided with lips. The hinge may be regarded as having two diverging teeth, each of which is cut across into numerous smaller ones. In old specimens these are often obsolete, and a ridge appears instead. In *Arca* proper, the shell is cockle-shaped, and lives freely in sand or mud, crawling on its crenated foot. In *Scapharca*, which abounds on the shores of the southern States, the valves are unequal, and generally thin. The American genus *Noëtia* is like an ark with one side cut off. *Argina*, also an American form, is more regular; but with one row of hinge teeth very short and twisted. In *Lunarca*, which closely resembles it in form, the short tooth is not serrated. *Trisis* has the valves shaped like *Byssoarca*, but curiously twisted. It has some resemblance to the curious little fresh-water Ark, *Scaphula*, from the East Indian rivers, in which however the teeth are rather transverse at the ends, forming a transition to *Cucullæa*. In this group the serrations of the teeth are normal in the middle, but parallel to the hinge line at the ends. The posterior muscular scar is bounded by a stout ridge. This form is now almost extinct, but in the oolitic and cretaceous strata it was very abundant. In the *Macrodon* group of the older rocks, only the shorter hinge tooth is serrated, the longer one remaining as in *Unio*.

One large group of Arks is completely sedentary in its habits, remaining fixed in crevices or old burrows. But instead of spinning a byssus like the Mussels and Pinnas, it adheres by the end of its foot, which deposits a number of horny plates, which can be cast off and renewed on special occasions. It appears more convenient to regard Cockle-arks (A. grandis, &c.) as the types of the family, and to call the fixed species *Byssoarca*. The typical forms have long straight hinges, winged on each side, with very numerous sharp teeth, and a gape in front where the creature fastens itself, with its face to the corner like a naughty boy. In the common form *Barbatia*, the wings are rounded off, the gape is not seen, and the hinge line is slightly curved, forming a transition to *Pectunculus*.

Fossil Arks are found in great numbers in every age, the palæozoic forms being chiefly of the *Cucullæa*, *Cucullella*, and *Isoarca* type. They live now at all depths, from low water to two hundred and thirty fathoms; and in all climates, from the equator to Prince Regent

Inlet. The form of the ligamental area is an important guide in the discrimination of species.

Another very abundant group resembles a flattened Cockle, with the beaks nearly close and the hinge-line curved. *Pectunculus* has a ligament like *Barbatia*, with very strongly marked muscular scars. The inner margin of the valves is crennated, as in the Fan-shells, and the free borders of the mantle have rudimentary eyelets to correspond. The lips are simply a prolongation of the gills; and the foot is large and crescent-shaped, waved on the sole. They are probably more active than the Arks. Half the species known are from the American shores, where they range from shallow water to a hundred fathoms. They first appear in the Neocomian age. The oldest shells of this group, being found from the Bath Oolite, have the ligament concentrated in a pit between the beaks, like *Lima*, and are thence called *Limopsis*. A few species are still living in the Old World, from Norway to the Cape. As *Macrodon* and *Lunarca* are to the Arks, so is the little crag fossil *Nucinella* to *Pectunculus*. On one side of the hinge the teeth are broken up, while on the other the plain ridge remains. A very similar shell has just been found living at Cape St. Lucas, by Mr. Xantus.

Family Nuculidæ. (*Nut-Shells.*)

The shells of *Nucula* are like a small, angular *Pectunculus*, with a pearly layer within. The cartilage is in an internal pit, and the hinge is in two divergent rows of very sharply interlocking teeth. They are generally covered with a smooth, horny skin, while that of the Arks is shaggy, and of *Pectunculus* velvety. The foot is very large, deeply grooved; spreading out to crawl into a broad disk with saw-like edges. The mantle flaps are freely open, without pipes; and the plume-like gills are small, and united behind. The lips are very long, curiously ornamented, and capable of protrusion outside of the valves, forming a singular contrast to the Arks, with which they are generally associated. The *Nuculas* are found in deep water and in all seas; they date from the earliest rocks, and are very numerous in species. *Nuculina*, from the French Eocenes, resembles *Nucinella*, but with an internal ligament; while *Stalagmium* and *Nucunella* form transitions to *Limopsis*.

Family Ledidæ. (*Beaked Nut-Shells.*)

This family, in most respects closely resembling the Nut-shells, and like them having the mantle freely open, presents us with the strange anomaly of a pair of regularly formed siphon pipes, reminding one of *Pandora* and the Anatinids. The shell of *Leda* is like a beaked *Nucula*, with a slight mantle-bend. The pipes are unequal and partially united; there being two flaps from the mantle which fold together like a third tube. The species are found in deep water from all seas, and abound in most ages from early times. *Yoldia*, which is almost entirely a boreal form, has the pipes united, with a deep mantle-bend, but no flaps. The shells are less pointed, and are found fossil in the newer tertiaries. A group of very transverse shells, with the hinge

lines almost straight, and gaping at each end, are called *Adrana*, and found in tropical seas. The animal of *Yoldia* is very active, and leaps very far on its bent foot. The group *Portlandia* has an irregularly swollen shell, truncated at the side. *Neilo* has a similarly-shaped shell, but not nacreous, and with the cartilage external. The mantle-edge is double, and furnished with flaps. It is found living in New Zealand, but fossil in Patagonia. *Solenella* is a similar shell from Chili, but shaped like *Sanguinolaria*, nacreous within, and with part of the anterior tooth remaining undivided, as in *Macrodon* and *Nucinella*.

Family TRIGONIADÆ.

The *Trigonia* race make their appearance in the secondary rocks, and abound as far as the cretaceous age; but in the tertiary series they have not yet been found. They linger however along with other old forms, in the Australian seas, presenting us with shells and animals of surpassing beauty. They have long, sharply-bent, pointed feet, like the Cockles, with which they can take surprising leaps. But they resemble the Arks in having the mantle freely open, the foot-sole crenulated, and the gills united. They are almost entirely nacreous within, and strongly sculptured outside. The hinge has 2-1 very large, deeply furrowed teeth. In many strata, the shell has entirely perished, leaving very characteristic internal casts, called "horse-heads" by the quarry men of the Portland oolite. *Myophoria* has a similar shell, but less sculptured. *Ascinus* makes its appearance in the Upper Silurian, with small, smooth teeth. Similar shells have been described as *Mactra*, *Isocardia*, *Anodontopsis*, *Anatina* and *Dolabra*. *Lyrodesma* is the earliest form in this family, with several radiating teeth, striated across. *Verticordia* is a small group from the newer tertiaries, and still living; with thin, nacreous, *Lucina*-shaped shells, with two Unioid teeth in each valve. The Eocene *Hippagus* has a similar shell without teeth. This family combines many of the characters of *Nucula*, *Castalia*, and *Cardium*.

Family AVICULIDÆ. (*Wing-Shells, Pearl and Hammer Oysters.*)

This extensive family of living and extinct forms are remarkable for the microscopic structure of the shells, as shown by Dr. W. B. Carpenter, (in the British Association Reports, before quoted.) The outside portion consists of large prisms; which in transparent young shells can be detected with a single glass, and in the old decaying shells of *Pinna* easily break up into needle-like fragments, resembling Arragonite. These have been formed by rows of simple shells, sometimes of different colors, piled one over the other. The fragments of the great *Inocerami* from the cretaceous rocks have the aspect of fossil wood. The same structure is found in the floats of *Belemnites*. The inside of the valves consists of true pearls, the beautiful iridescence of which is caused by very finely wrinkled skins, with layers of shell between. After the shell has been dissolved in acid, and the wrinkles flattened out, the iridescence ceases. Many of the fossil forms have shells intermediate in form between *Avicula* and *Pecten;* but their

family relationships can always be determined by the microscopic examination of any small fragment; the prismatic structure not being seen in the Fan-shells.

The animal of the Pearl-oysters has the mantle free all round, except where the flaps are joined, in the middle, by the attachment of the gills. The edges are beautifully fringed. The lips are plain, and rather small. There is only one principal adductor muscle in this and the remaining families of the Pectinibranchs; although there are often seen other small scars, formed by the foot-muscles and the retractors of the mantle. The foot is finger-like and grooved, working through a notch at the side of the shell, and spinning a byssus, which in *Pinna* is long and silky, but in other genera is horny and rather solid.

All the Aviculids which have been observed in the young state have the pointed shape of the Mussels, which is permanent in the *Pinnas*. These creatures, which are sometimes two feet long, stick their pointed beaks in the sand or mud, with the knife-like edges of their gaping shells projecting upwards. These are sometimes dangerous to navigation. They differ from the ordinary Wing-Shells in having the small anterior adductor somewhat developed. A little crab (called "Pinna-guardian" by Aristotle; perhaps the mollusk calls it Pinna-plague) is fond of nestling in its breathing cavity. Fossil species are found from the Devonian age; some of the thick oolitic forms being grouped as *Trichites*.

The typical *Avicula* tribe have thin, slanting shells, swollen in the middle, and produced on each side of the hinge into wings which are some times very long, but greatly vary in the same species. They are fond of mooring themselves to *Gorgonias*, floating wood, and other light bodies. One valve is generally larger than the other; and there are small hinge-teeth as in *Alasmodon*. The fossil species are very numerous, beginning from the earliest rocks.

The Pearl-oysters, (*Margaritiphora*,) have heavy shells with short wings, having thick layers of "mother o'pearl," beautiful wherever it is worked. The pearls themselves are formed by excrescenses or deposits of pearly matter in the mantle, often taking form from sand or other extraneous substance which has been introduced. Nearly three hundred tons of this shell are yearly imported into England. They have no hinge teeth. In this respect they resemble the Hammer-oysters, (*Malleus*,) which take the contrary extreme of shape. The body and the side-wings being all very long and narrow, the shell takes the form of a T. In the young shells, which are often regarded as distinct species, the side wings are not developed. The shape then resembles the *Vulsella*, which lives embedded in sponge, and has the ligament concentrated in a spoon-shaped cavity. Some of the early fossil forms have been grouped as *Ambonychia*, *Cardiola*, and *Eurydesma*. *Monotis* and *Halobia* are from the Triassic rocks. The Silurian *Pterinea* and the oolitic *Pteroperna* have few or numerous anterior teeth, and long posterior teeth as in *Unio*. The ancient *Posidonomya* has a thin, earless shell, without teeth.

In the remaining group of this family, the young shell is like *Avicula*, but in the adult the ligament is fixed into numerous pits along the hinge line. The name *Perna*, given by Lamarck to the common

forms, with square pits, has been used by different authors in such various ways that it may be convenient to revive the old name *Isognomon*, (or *Melina*.) In some of the tertiary fossils, the pearly layer is an inch thick. *Crenatula* has the pits small and rounded. In the fossil *Gervillia* and *Bakewellia*, which abound in the secondary strata, there are long hinge teeth inside the ligament row. *Inoceramus*, which is very characteristic of the cretaceous age, has the shell and the hinge rounded. Some species are a yard long. Other fossil forms are *Hypotrema*, *Catillus*, *Pulvinites*, and possibly *Pachymya*.

Family Pectenidæ. (*Fan-Shells*, or *Scallops*.)

The Fan-shells are at once recognized by the broad ears on each side of the beaks, with a slit in one valve for the passage of the foot and byssus. The animals have a double edge to the free mantle; the inner hanging like a fringed curtain, the outer bordered with a row of minute eyelets, each of which is protected by filaments. The gills are extremely delicate, and hang loose. The lips are beautifully cut. The shell consists almost entirely of membranous plates laid over each other. In the young state all the species moor themselves by a lyssus, which some do permanently. Others live freely, either few together, or in great scallop banks. They can swim by flapping their valves, often jerking themselves some yards at once. They do not abound on the west coast of the Atlantic; but in most seas they are numerous, and generally very highly sculptured and painted; the lower valve often having a very different hue from the other. Mollusk-eaters consider them great delicacies. The cartilage is in an internal pit. The typical *Pectens* have the valves nearly equal. In *Amusium* one is generally larger than the other; the shell gapes at the sides; and the valves are either smooth or irregularly waved. In *Janira*, which includes some of the finest species of the tribe, one valve is flat or even concave, while the other bulges. The *J. jacobæa* of the Mediterranean was formerly worn by pilgrims who had been to the Holy Land. *Pallium* differs from the ordinary Scallops in having teeth on each side of the hinge-plate. *Neithea* differs from *Janira* in the same way. *Hemipecten* has only one ear; the other being incorporated into the shell. Fossil species are plentiful in all ages from the carboniferous. Those of *Aucella* and *Aviculopecten* form the transition to the Aviculids.

Family Limidæ.

The *Lima* group differ from the true *Pectens* in having no eyelets on the outer mantle-margin, and in having the inner fringed with very long and numerous tentacles. The shells are always white; and the inner layer is pierced with a network of minute tubes. The ligament is in an external pit, like *Vulsella*, and the ears are very small. The creatures can swim by jerking their valves, like the Pectens. They either live free, or moor themselves by a byssus; or make a nest of stones and broken shells, spun together by byssal threads, in which they completely hide themselves. Fossil species are extremely numerous, from the carboniferous age; and abound in the Lias and oolites,

where they are often of large size, and are called *Plagiostoma*. *Limæa* begins with the Lias, and has one recent representative. It is a *Lima* with a row of Arca-like hinge teeth. *Limatula*, a northern group which begins in the English Crag, has the valves equilateral.

Family SPONDYLIDÆ. (*Thorn-Oysters.*)

These creatures may be regarded as attached Fan-shells; and form a natural transition from them to the true Oysters. The animal of *Spondylus* closely resembles that of *Pecten*, but the foot is rather more rudimentary, and there are no eyelets. The shell has strong interlocking teeth, and the attached valve has a very long beak, with a flat area, which is wanting in *Plicatula*. In one specimen of the "Water-clam" (so called from the layers of shell having spaces between them) in the Smithsonian Museum, there is an area in both valves. Fossil species are found from the lower oolites. The *Spondylus spinosus*, a very characteristic species of the chalk, lived nearly free; like the recent *S. imperialis*. *Hinnites* begins free like a *Pecten*, and afterwards becomes fixed. *Pedum* has a thin, flat shell; living imbedded in madrepores. It has a deep notch for a byssus in the lower valve.

Family OSTREIDÆ. (*Oysters.*)

As all readers of this report have access to Oysters, which, instead of eating, they can dissect and examine at pleasure, it is needless to describe either the shell or the animal. The chief peculiarity is the entire absence of foot. They are found in all seas, and in every age from the carboniferous; varying greatly in form, according to the surface to which they have been attached. The mangrove-oysters (*Dendrostrea*) are thin and but slightly attached. The cock's-comb species are deeply plicated. In the fossil genus *Gryphæa* one valve is spirally twisted, and the other nearly flat. The animal was probably not attached. The shell of *Exogyra*, characteristic of the oolitic and cretaceous ages, is *Chama*-shaped. The fossil *Ostrea longirostris* of the Tagus is sometimes two feet long.

Family PLACUNIDÆ. (*Window-Shells.*)

The Placunids are extremely flat, thin creatures, with a very unusual hinge. There are two long divergent teeth, like a V, to the sides of which the ligament is attached, as in *Pandora*, to which the shell offers some resemblances. It consists of very thin, somewhat nacreous plates. The shells of *Placuna*, often called Saddle-oysters from their shape, have the hinge-ridges equal, and rapidly diverging. Those of *Placenta* are nearly transparent, being used for window glass by the Chinese; and have the hinge ridges nearer, and one shorter than the other. *Placunopsis* is an oolitic fossil, with a transverse ligament groove. There is only one principal muscular impression in the Placunids.

Family ANOMIADÆ.

The shells of this family are remarkable for the large number of

muscular impressions in the convex valve. The flat valve is pierced by a hole, which is filled up by a shelly plug, which is more or less separate from the valve. The animal differs from the Oysters in having a small foot, connected with the plug which takes the place of the byssus in the mussels. The convex valve has four scars, of which the largest is made by the plug muscle, and the front one by the adductor. The third central scar, and one near the internal cartilage, are made by the retractors of the foot. The *Anomias* are extremely thin and pearly, found in all parts of the world, and in all ages from the oolites. In *Placunanomia*, there are only two instead of three muscular scars. The hinge fulcrum is notched, and the plug often becomes imbedded in the lower valve. The fossil *Limanomia* is eared like *Lima*. *Carolia* has a plug when young, like *Anomia;* but when adult it resembles *Placunopsis*, and might be ranked with either family. It belongs to the tertiary age.

The species in this family ought always to be studied in connection with their geographical relationships ; and the young animals ought especially to be examined, as being less likely to be affected by the disturbing influences of later life.

CLASS PALLIOBRANCHIATA.

(*Mantle-breathers*, or *Brachiopods*.)

The Palliobranchiate bivalves may be considered as a parallel group with the Lamellibranchs, but inferior to them; as the Implacental as compared with the Placental Mammals. They are always attached, either by the surface of the valve, or by a peduncle passing through a hole, as in the Anomids. The resemblance however which caused Linnæus to unite *Terebratula* with *Anomia* is only superficial. The valves, instead of being side wings, are front and back shields. There are no true ligaments or hinge teeth. Above all, there are no gills ; the breathing being performed by the general surface of the skin. The water-currents are established by the action of cilia and variously twisted "*arms*," which gave Lamarck the class-name *Brachiopoda*. But they are not, in any strict sense, arms or feet; not being used for locomotion; but on the contrary correspond to the *lips* of the Lamellibranchs, their office being to waft the food-particles to the mouth. They are generally fixed to a shelly skeleton within, the form of which is very characteristic of the genera. The valves of the Lamp-shells are fastened by interlocking teeth; but the work of ligaments is performed by a set of muscles which act in the opposite direction from the adductors. After the skin and lips are deducted, the body of the animal remains in but a small portion at the back of the shell, often partitioned off by a strong membrane, in the centre of which is the mouth.

As there is no special breathing organ, the mantle is more than usually supplied with blood vessels, and adorned with various filaments. The marks of the blood vessels may often be traced in the valves of fossil shells. These display far more of the peculiarities of the animal than do the valves of Lamellibranchs, in which the hinge is almost the only safe guide to their affinities. It is therefore fortunate that so

very large a proportion of the fossil bivalves, up to the tertiary age, belong to this class.

The structure of the shells is more simple than in the ordinary bivalve and univalve tribes. There is no distinction between the outer and inner layers; the whole consisting of long flattened prisms, arranged sideways. In most of the families these are traversed by numerous vertical tubes, which are trumpet-shaped outside and sometimes arborescent. As the valves open but a little way, and there are no specially directed breathing currents, the tubes which are no doubt occupied by prolongations from the mantle (which is not loose, as in ordinary bivalves) assist greatly either in the breathing or excretory functions. There are no pores in the internal lip skeleton.

In the ancient rocks both of the Old and New World, a *Lingula* is the first organic "footprint on the sands of time," the same generic form being still found in all the oceans of the globe. As we read onwards in the palæozoic chronicles, the forms, and still more the number of specimens, continue prominent, typical, and diagnostic above all other fossils until they reach their maximum of development in the Devonian ages. They continue extremely abundant throughout all the secondary and cretaceous ages; decreasing in comparative importance as the Lamellibranchs gradually appear. The *Productus* tribe does not enter the secondary period; the *Spirifers* and *Orthids* die out in the lower beds; while the *Rhynconellids*, *Craniads*, and *Lingulas* have maintained their position, throughout all the changes in other races of animals, throughout all the fossil ages, to the present time. The *Terebratulids* were the latest to appear, not showing themselves decisively till the carboniferous age. Most of the tertiary and living forms belong to this group. Although the Palliobranchs are comparatively rare in the tertiary ages, the boreal Crag furnishes us with one of the largest species known. No members of this class attain the size of the Lamellibranchs; a more complete system for breathing and digestion being necessary to maintain a Scallop, a Panopæa, or a giant clam.

It used to be thought that the prevalence of Palliobranchs in any stratum was a sure evidence of deep-sea origin. It is true that they are found living in the greatest depths yet dredged; but species are also found in pools left by the retiring tide; and it is probable that many of the earliest rocks were deposited in comparatively shallow water. Although the recent shells are still rare in collections, they are common in the regions they inhabit; and as seventy species are already known, a greater number than has been discovered in any *single* secondary stratum, and as probably more than half the living forms are yet to be discovered, we have no right to say that the race are dying out. While some species are very local, other forms are widely diffused both in area and in time. The *Atrypa reticularis* is found through a whole series of strata, in the Old and in the New World; and *Spirifera striata* ranges from the Cordillera to the Ural mountains.

The fullest account of the shells and physiology of this class will be found in Davidson's treatise on the "British Fossil Brachiopoda," printed by the Palæontographical Society. A very full abstract of

everything known up to the date of publication, illustrated by many of the woodcuts in Davidson's work, will be found in "Woodward's Manual of the Mollusca," pp. 209–240, and 465–467. Additional genera are described by Prof. Hall in the annual Reports of the Regents of the University of New York. Those who wish to examine magnificent series of the shells of the older rocks, exhibiting the internal structure, are specially directed to the private collection of Prof. Hall, and to the Museum of the Geological Survey of Canada, arranged at Montreal under the direction of Sir W. Logan. The following is a sketch of the principal groups; but as the distinctions of the genera depend principally on the form of the lip-skeleton, which can be best understood by figures, they will only here be indicated.

Family TEREBRATULIDÆ. (*Lamp-Shells.*)

The Lamp-shells lie on their back, which is shielded by the smaller valve; the front valve bends over, and is pierced at the beak by a hole through which a peduncle anchors the animal to foreign objects. This presents a fanciful resemblance to the plug of the Anomiads; but, instead of being a side-bunch, produced by the foot, it is a lump which grows of itself behind the mouth; as though a Chinese mandarin were laid on his back and fastened by his hair-tail. So there is a resemblance between the mouth-arms of the Palliobranchs and the mouth-feelers of the four-gilled Cephalopods, Dr. Gray grouping these classes on each side of the Pteropods; but the likeness is almost as artificial as if we should compare the Star-fish with the Cuttles, both groups having locomotive organs round the mouth.

Terebratula proper is thin and smooth, with a very short loop. This only joins into a horseshoe; in the striated shells of *Terebratulina*, it unites into a ring. In *Waldheimia*, the shell is somewhat plaited, and the loop is very long and reflected. *Eudesia* differs in being sharply plaited. *Meganteris* is a long-looped Devonian form. In this group the loop is attached near the end of the back valve.

In *Terebratella* and its neighbors the loop is joined along the middle of the valve, to a perpendicular plate. The cretaceous *Trigonosemus* has a prominent, curved beak. *Lyra* (also cretaceous) has a long, ribbed beak. *Magas* has the reflected parts of the loop disunited. In *Bouchardia* the peduncle plate (called "deltidium," and separating the hole from the hinge) is blended with the shell. *Morrisia* is moored mouth-upwards, the hole being scooped out of both valves.

Kraussia is a southern form, with the beak truncated. *Megerlia* is also truncated, with the loop trebly attached. *Ismenia* has the valves ornamented with corresponding ribs; and *Kingena* has the surface spiny.

Family THECIDIADÆ.

Thecidium has no hole, but is attached by the beak to sea-urchins, corals, &c. *Argiope* resembles it in general aspect, but has a peduncle through the truncated valve. The mouth-arms are folded into four lobes; in *Cistella*, into two. *Stringocephalus* is a similar form from the Devonian; and *Zellania* resembles *Thecidium*, from the secondary rocks.

Family SPIRIFERIDÆ.

In this extinct group, the mouth-arms were supported by very large

spiral coils, which occupy almost the whole of the sides of the shell. These are sometimes spiny, showing that they were covered with stiff cilia. In some members of this family the shell is pierced by tubes; in others not; but in metamorphic rocks it is very difficult to speak positively on this point. The species of *Spirifera* are found in palæozioc rocks all over the world. They are generally very transverse, like *Argiope*. *Cyrtia* has a pyramidal shape, with a prominent beak. *Spiriferina* and *Suessia* include the secondary forms, with a prominent plate inside the upper valve. *Athyris* (*Spirigera*) is shaped like a smooth *Terebratula*. *Merista* resembles it, with arched plates round the hinge. *Retzia* is punctured, like a *Terebratulina* with spiral arms. *Uncites* is not punctured, has no hinge area, and is furnished with a large concave deltidium, approaching *Pentamerus*.

Family Rhynconellidæ.

Rhynconella has long, spiral mouth-arms, directed inwards, (not outwards, as in the *Spirifers*,) and not supported by any shelly skeleton. The shell is not punctured, leaving the mantle loose. The living species are black and slightly plaited; the fossils are very numerous, and generally deeply plaited, with the margin of the valves twisted. In *Porambonites*, the surface is minutely pitted. *Camarophoria* has ridges supporting dental plates. In this respect it resembles *Pentamerus*, in which the plates are so magnified as nearly to divide each of the valves. They branch in the middle, so as to inclose a separate chamber in which the viscera were probably situated. *Atrypa* resembles *Rhynconella*, but with the mouth-arms calcified.

Family Orthidæ.

The Orthids have punctate shells, generally very much depressed; with small beaks and straight hinge. They probably had horizontally-coiled spiral arms. In *Orthis*, the hinge-line is narrower than the shell, and both valves are convex. In *Orthisina*, it is wider. *Streptorhyncus* has the beak twisted. *Strophomena* is widest at the hinge-line. The valves are nearly flat during adolescence; when they approach maturity, they suddenly bend to one side. *Stropheodonta* has a toothed hinged-line. The restricted genus *Leptæna* has the valves regularly curved. *Koninckia* has the valves rounded and smooth. *Davidsonia* was attached by the outer surface of the ventral valve. *Calceola* is generally reckoned with the "Rudistes;" all of which are, by Philippi and others, ranked with this family. It is funnel-shaped, resembling *Radiolites;* but the internal markings indicate strong affinities with the Orthids. The true *Calceolas* are a Devonian group; the so-called Carboniferous group, *Hypodema*, are believed to be Capulid Gasteropods.

Family Productidæ.

In this singular group, the creatures were bent backwards; the back valve being concave, and the front valve very convex. They were probably attached by the long hollow spines, which adorn the shells; and may have moored themselves in chinks, or partly buried in mud. *Productus* has the hinge-line linear, and is a Devonian group. *Aulosteges* has a hinge-area, like *Spondylus*. *Strophalosia* was attached by the beak of the front valve. The Silurian *Chonetes* has one row of spines along the hinge-line of the front valve.

Family CRANIADÆ.

The *Cranias* have lived from the palæozoic times till now. They have no hinge, and are attached by the front valve: the back valve being limpet shaped. The mouth-arms are free, supported by a nose-like projection in the front valve. The eye-like muscular scars give some of the species a rude resemblance to a skull. The valves are shelly, and very minutely punctured. The ancient *Pseudocrania* had the valves free. The position of *Spondilobolus* is uncertain.

Family DISCINIDÆ.

The shells of *Discina* are quite horny, and flexible when fresh. They are attached by a peduncle, passing through a chink in the lower valve. The mantle is surrounded by stiff bristles; but the cilia on the mouth-arms are very tender and flexible. The ancient fossils have been separated as *Orbiculoidea*. *Trematis* has convex valves, with a thickened hinge-margin. *Siphonotreta* is covered with hollow spines, with a tubular hole at the beak. *Acrotreta* is shaped like *Calceola*.

Family LINGULIDÆ.

As the *Lingulas* are the earliest, so they may be regarded as the lowest bivalve shells. They live half buried in sand or mud, often at slight depths; and, as their horny shells hang at the end of a very long peduncle, they have no slight resemblance to the Lepad Barnacles. Members of the group lived in all ages in the British seas, down to the Coralline Crag; and a species is still living on the Atlantic shores of North America. The Silurian form *Obolus* is nearly round, with a thickened hinge-margin.

CLASS TUNICATA.

(*Tunicaries*, or *Cloaked Mollusks.*)

We have now completed our sketch of the shell-bearing classes of Mollusks. The remaining groups form a transition to the zoophytic condition of animal life. The higher Tunicaries offer many points of similarity with the sedentary Lamellibranchs; but the lower races lose their separate individuality, and become incorporated into a general mass of life, like the Polypes. Although not attractive to the general observer, they present many points of singular interest to the scientific student. They have lately been carefully examined and reported on by Huxley and Rupert Jones. The first group are the solitary or simple Ascidians.

Family ASCIDIADÆ. (*Sea-Squirts.*)

The Sea-squirts appear at first sight nothing but leathery bags, covered perhaps with sea-weed or other accretions. The presence of organic life is only made known to us by the violent jets of water which they force out when disturbed. This leathery bag or "test" takes the place of the shell in the bivalves. It is less distinctly animal in its nature than any other substance produced by sentient life, containing a large quantity of the vegetative *cellulose*. It is freely bored into by bivalve mollusks, such as *Crenella* and *Mytilimeria*. But under this test, is found a delicate mantle, like that of ordinary mollusks, united into a sac, and terminating in two openings, the inha-

lent and excurrent. The bulk of the body is occupied by the branchial sac, the mouth and all the viscera being collected into a small space at the bottom. If the test were removed and a Mya-shell placed over the inner mantle, the creature might pass for a Lamellibranch. But there are no true gills; the respiration being performed by the more or less wrinkled lining of the water chamber: there is no foot: the mouth has no lips to choose its food: there is no complete circulating system; the blood being carried backwards and forwards along the same vessels; and the reproductive functions are of so low an order that fresh individuals can be produced by budding, as in plants. The Ascidians are always fixed at the bottom of their squirts, and may often be gathered on the fronds of sea-weeds, shells, &c. In many places they are taken to market, and even considered dainty articles of food. The *Ascidia* vary from one to six inches in length, and often are brilliantly colored within. *Molgula* and *Glandula* have globular bodies, differing in the number of lobes at the apertures. *Cynthia* has a basket-shaped body, with two ovaries; *Dendrodoa* has only the left, and *Pandocia* the right ovary. *Pera* has a pear-shaped body, scarcely adhering. *Pelonœa* has a long body, ending in the two pipes, and looks like the outside portion of a *Panopœa*. *Chelyosoma* is a Greenland form, with a tortoise-shaped body. *Boltenia* is kidney-shaped, resting on a long stalk, on which the young ones sometimes grow.

Family CLAVELLINIDÆ. (*Social Ascidians.*)

Here, for the first time as we descend downwards in the animal scale, we meet with several living creatures, each having their own organs of individual life, but all connected together into a common life by prolongations from a central stem or creeper, in which the common blood keeps circulating in opposite directions. The compound creature is called a *Zoöid*. The creatures are quite transparent, and very small. New creatures are formed by buddings-off from the common stem, as well as by fresh eggs. *Clavellina* looks like a bunch of *Cineras*. *Perophora* grows on sea-weed, like little specks of jelly dotted with orange and brown. *Syntethis* grows in dahlia-shaped masses six inches across. The zooid of *Chondrostachys* has a long cylindrical stem.

Family BOTRYLLIDÆ. (*Compound Ascidians.*)

These creatures have their tests fused into a common mass, so that each zooid looks like a single animal outside; but the individuals are found to be separate within. In the *Botryllians*, the individuals are united into systems round common excretary cavities. In the *Didemnians*, the chest and abdomen are distinct. In the *Polyclinians*, there is a chest, with the breathing organs; an upper abdomen, with the digestive organs; and a lower abdomen, with the heart (so called) and reproductive organs.

In *Botryllus*, the breathing-holes are star-shaped, the cloaca being poured into a common sewer. In *Botrylloides*, the stars are more irregular, and the animals are vertical.

The zooid of *Didemnium* is very irregular, the individuals with a pedunculate abdomen. In *Eucœlium*, the animals are scattered, or arranged in quincunx. *Leptoclinum* makes thin, variously colored

zooids, adhering to the roots of tangles. *Distomus* and *Diazona* are bistellate, the latter being flower-shaped, like *Syntethys*.

Sigillina is also bistellate; *i. e.* both the mouth and anal orifice are rayed. The zooid grows like a plantain. In the remaining genera, the mouth only is rayed. *Polyclinum* has a fungus-shaped mass. The *Aplidia* or Sea-figs have often been confounded with *Alcyonium*. *Sidnyum* forms transparent, amber-colored masses under shelving rocks at extreme low water. *Synœcium* is an arctic form, with a stalked zooid. *Amœrœcium* has a common central cloaca to the pod-shaped zooid.

Family PYROSOMIDÆ.

The *Pyrosomes* combine in innumerable numbers to form hollow transparent tubes, open at one end, which receive the common cloaca. These tubes, or zooids, are from two to fourteen inches long, and an inch across. The mouths are outside; and by the combined force of the exhalent currents, the zooid is driven forward in the open sea with the closed end forward, reminding us in a feeble manner of the squirt-swimming of the Cuttles. They increase by buds or by eggs: and often fill the sea in such vast numbers as greatly to incommode the nets of fishermen. At night they are brilliantly phosphorescent, resembling "incandescent cylinders of iron." Humboldt observed them as forming lights, eighteen inches in diameter, by which the fishes were made visible.

Family SALPIDÆ.

The *Salpas* first exhibit to us the zoophitic condition of alternate generation. No *Salpa* is like its parent or its child; but always resembles its grandparent or grandchild. The creatures of one generation therefore do not exhibit to us the whole Salpoid structure. Just as in the higher animals we must have two individuals, male and female, before we can gain a complete idea of the species; so in the *Salpas* we must see two generations, mother and child, before we can understand the complete Salphine zooid. The *Salpas* are found under two very contrary conditions; as free individuals and as serpentine chains of compound animals. That they were the same, was first discovered by Chamisso, the author of the well-known "Man without a Shadow." The solitary Salp always gives birth to the compound, and those again to the single. *Doliolum* is intermediate between *Salpa* and *Pyrosoma*.

Family APPENDICULARIADÆ. (*Larval Ascidians.*)

The minute *Appendicularias* appear as cloudy patches of red coloring matter in the northern seas. They are little tadpole-shaped creatures, and resemble the larval stage of the higher tribes of Tunicaries, arrested at the first period of growth.

CLASS POLYZOA.

Among the creatures generally grouped together as zoophytes, and forming the structures usually known as "Corallines," "Sea-weeds," &c., are many which are found to have a much more complex organization than the rest. There is an excurrent opening distinct from the inhalent cavity; and though their general habit of life resembles the

true zoophytes, yet there is sufficient analogy between them and the compound Tunicaries to entitle them to a place in the molluscan subkingdom. They differ from even the lowest Tunicaries, in not having any special circulating vessels; the fluids being generally transmitted through the transparent mass of the tiny bodies. They have been designated both as *Polyzoa* and *Bryozoa;* the former name being the earliest, the latter the most distinctive as a class. By some authors they are considered as superior Radiates, by others as degraded Mollusks. The balance of characters seems in favor of the latter view; but as they are more conveniently studied in common with the true zoophytes, and are generally described in treatises concerning the latter, they will not be further considered here. Those who are at the sea-shore, and can examine the "sea-mats" and *Lepralias* in their living state under the microscope, will do well to examine the differences between them and the common Sertularian Polypes. Some of the forms are peculiar to fresh waters. The test formed by their compound zooids is often somewhat calcareous. Their remains are extremely abundant in the Coralline Crag; and even in the palæozoic rocks, they play an important part among the fossil keys to knowledge. It must be borne in mind however that many of the objects described loosely as *Bryozoa* have no relation to this class.

Those who desire information on this interesting class of creatures are referred to "Johnstone's British Zoophytes," and to the works of George Busk, Esq., published by the British Museum.

On bringing to a close this brief digest of our existing knowledge of molluscous animals, any one who will take the trouble to compare the nomenclature and arrangement here adopted with that of any one or more of the principal treatises on the subject, will be struck with the general want of harmony which prevails among the different authorities. It will not help us out of our difficulties to ignore their existence. In the old days when all knowledge was supposed to be centered in Lamarck, we had nothing to do but to study his system and follow it. We are now turned loose on a new sea of inquiry; where every voyager makes his own discoveries, which is right; and his own speculations, which may be correct or very erroneous.

Our uncertainties for want of knowledge are quite sufficiently discouraging; but for these we must be prepared. With every fresh, patient, and honest observation, these will be steadily lessened, in spite of the prejudice and human tempers which ought not indeed to be allowed to enter into the domain of science, but alas! are to be found there as rife as in any other department where men enter on each other's paths. And it ought to be an incentive to pursue this branch of study that there is so much to be done; and so much, too, the materials for which are easily accessible. The principal requisites to insure really useful results are not indeed great talents or special acquirements, which fall to the lot of but few; but what an ordinary person may possess himself of, an accurate eye, patience, and honesty.

It is well, in the present state of science, to take nothing on trust. What is copied from book to book, and what is repeated from figure to figure, may be correct; "but then, on the other hand, it may not." Very few can examine all things with their own eyes; and the greatest

authors take many things on trust, which humble students may prove to be unfounded. It is a mistake to suppose that the evidence of the senses is infallible. The eye has to be trained to see, just as much as the ear to appreciate false and true harmonies, or the hand to discriminate weights. Very few persons at the beginning of their investigations see things in the microscope as they do after long study. The best artist, if required to draw a shell, might very likely overlook features which a student has learned to see at once. Therefore let a man work some time, comparing his observations with the books, and repeating them under different conditions, before he considers himself competent to trust his own eyesight.

Let the student especially avoid hasty conclusions. Because character A is found to be coördinate with character *a* in one class of shells, let him not infer that it is so in another; still less that character B is coördinate with character *b*. The following table may serve as a lesson of caution, to show how little can be gathered from general similarity in appearance. It furnishes some of the more striking examples of Gasteropods similar in form of shell, but known to belong to different families by peculiarities in the animal.

TABLE OF SIMILAR SHELLS, BELONGING TO DIFFERENT FAMILIES OR GENERA.

Murex, *Muricidæ*. Cerastoma and Vitularia, *Purpuridæ*. Ranella and Triton, *Tritonidæ*.
Chrysodomus, *Muricidæ*. Strombella, *Buccinidæ*. Io, *Melaniadæ*.
Engina, *Muricidæ*. Ricinula, *Purpuridæ*.
Anachis, *Muricidæ*. Nitidella, *Purpuridæ*. Columbella, *Buccinidæ*.
Cominella, *Muricidæ*. Buccinum, *Buccinidæ*. Truncaria, ? *Purpuridæ*.
Pisania, *Muricidæ*. Iopas, *Purpuridæ*. Peristernia, *Fasciolariadæ*.
Pyrula, *Pyrulidæ*. Fulgur, *Fasciolariadæ*. Rapana, *Purpuridæ*. Ficula, *Ficulidæ*.
Leucozonia, *Fasciolariadæ*. Monoceros, *Purpuridæ*.
Mitra, *Fasciolariadæ*. Turricula, *Turriculidæ*. Volutomitra, *Volutidæ*.
Aulica, *Volutidæ*. Amoria, *Do*.
Metula, ? *Muricidæ*. Daphnella, *Pleurotomidæ*.
Marginella, *Marginellidæ*. Erato. *Cypræidæ*.
Cerithiopsis, *Cerithiopsidæ*. Fastigiella, ? *Fasciolariadæ*. Cerithium, *Cerithiadæ*.
Velutina, *Velutinidæ*. Capulus, *Capulidæ*. Otina, *Otinidæ*.
Sigaretus, *Naticidæ*. Lamellaria, *Lamellariadæ*. Stomatella, *Stomatidæ*.
Drillia, *Pleurotomidæ*. Clionella, *Melaniadæ*.
Lunatia, *Naticidæ*. Lacuna, sp. *Lacunidæ*. Pachistoma, *Ampullariadæ*.
Naticina, *Naticidæ*. Narica, *Naricidæ*. Fossarus, *Litorinidæ*.
Menestho, *Pyramidellidæ*. Mesalia, *Turritellidæ*. Melania, *Melaniadæ*.
Aclis, *Pyramidellidæ*. Turritella, *Turritellidæ*.
Top-shells in general, e. g.: Solarium, *Solariadæ*. Phorus, *Phoridæ*. Risella, *Litorinidæ*. Trochita, *Calyptræidæ*. Trochatella, *Helicinidæ*.

Especially: Phorus, *Phoridæ*, Guildfordia. *Turbidæ*. Torinia, *Solariadæ*. Monilea, *Trochidæ*. Infundibulum, *Trochidæ*. Trochita, *Calyptræidæ*.
Rostellaria, *Strombidæ*. Aporrhais, *Aporrhaidæ*.
Tanalia, *Paludinidæ*. Paludomus, *Melaniadæ*.
Vermetus, *Vermetidæ*. Serpula, ANNELIDS.
Dentalium, *Dentaliadæ*. Ditrupa, ANNELIDS.
Planorbis, *Planorbidæ*. Marisa, *Ampullariadæ*. Polygira, *Helicidæ*.
Limpets in general, e. g.: Patella, *Patellidæ*. Acmæa, *Acmæidæ*. Amalthea, *Capulidæ*. Gadinia, *Gadiniadæ*. Siphonaria, *Siphonariadæ*. Broderipia, *Stomatidæ*. Umbrella, *Umbrellidæ*.
Especially: Nacella, *Patellidæ*. Ancylus, *Planorbidæ*. Latia, *Planorbidæ*. Crepidula, *Calyptræidæ*. Tylodina, *Umbrellidiæ*. Scurria, *Armæidæ*.
Amphibola, *Amphibolidæ*. Scissurella, *Scissurellidæ*.
Achatina, *Helicidæ*. Glandina, *Testacellidæ*, &c. &c.

A similar table might easily be prepared of shells very greatly differing in appearance, which are known to belong to the same family.

This branch of study has been favored with quite a sufficient number of hasty generalizations to last for some time to come. What we want now is patient verification of the past, and cautious observation for the future. "*Non omnes possumus omnia*," and every man is not bound to do his work well; because he cannot; but he *is* bound honestly to use all the materials at his command. There is so much yet to be known about the commonest land and fresh-water shells, in their anatomy, habits, distribution, and specific differences; and there are so many materials hoarded up in museums awaiting the study of naturalists, that all who are disposed to train their eyes and set to work can easily find the means for useful service.

The objects of the Smithsonian Institution are both the *increase* and the *diffusion* of knowledge. So very much confusion is constantly arising from wrongly or uncertainly named specimens, that those who are not prepared to increase existing knowledge can make themselves very useful simply by diffusing the knowledge of others. On comparing together the American shells given me by a number of accurate and trustworthy American naturalists, I find myself considerably bewildered, not merely by the wrong names which are given, but by names given as by Lea, Say, and other distinguished authors, which contradict themselves, and therefore cannot be depended upon. These difficulties are to be met by the copious diffusion of specimens *named from types*. All that can thus be vouched for have a peculiar value, especially in a foreign country: and if collectors will merely amass a multitude of specimens, and see to their being named by those who possess the typical knowledge, the Smithsonian Institution will see to their being made available for the purposes of science. It is not necessary for the uses of science that the name given should ultimately stand as the correct one. Whether, *e. g.*, among the Unios, a name of Lea or of Rafinesque be permanently chosen, matters little. What we want to know is that such a shell is really the Unio —— of Lea, or the Unio —— of Conrad. When it is known accurately what each author means by his own descriptions, his successors have something tangi-

ble to work upon. At present a large proportion of every author's time is taken up with trying to find out, and that under ordinary circumstances with necessary errors, what his predecessors mean. If this is true even of the most careful writers, such as C. B. Adams, Conrad, &c , what can be said of the imagination of Rafinesque.

As to questions of generic nomenclature, it is hoped that the present climax of confusion will make the necessity felt of agreeing on some common basis. At present some writers endeavor to follow the rules of the British and American associations ; others avowedly set them at defiance. To revive the careless work of old writers, to the upsetting of those whose useful toil has been recognized by general acceptance, appears worse than folly. If any one will compare the names of the Messrs. Adams and of Dr. Gray, who profess to follow the same rule of absolute priority, it will be found that ancient genera were so ill defined that even those who most desire to understand them, have interpreted them quite differently. Under these circumstances, it is well for ardent young naturalists not necessarily to adopt all the interpretations now offered of old names, from the bewitching love of novelty ; but to remember that *use* and *accuracy* are matters far more important than supposed justice to men whose works might as well have been forgotten. Every naturalist ought to start with a feeling that it is of no consequence what becomes of his own names and his own reputation, if the "increase and diffusion of knowledge among men" is promoted by his own retirement ; and what he thus feels for himself, he should be willing to accord to those whose works are as inaccessible as they have proved to be injuriously confusing. In arranging the nomenclature for this report, we have endeavored to preserve as far as possible the names in common use; and when dead names have been revived, they are taken not as the works of Link or Klein, but as the names of Gray or Adams, who have given an accurate diagnosis to what before was of uncertain import. By all means, let us spend our time in the living present. The naturalist is not required to be the archæologist.

The study of Mollusks in connection with their geographical distribution is a matter of the very first importance. For this reason, all persons who will carefully note what shells are found living, what dead, and what fossil, in their own localities, and distribute them accordingly, may be rendering the most essential service. Our knowledge of the American faunas is by no means so complete as of those of Europe : and as men of intelligence are now to be found in every part of the continent, and the young are now learning freely in the public schools what in the Old World has long been the property only of the learned few, we ought to find our information accumulating with giant strides.

To young naturalists, we may be allowed to say that he who will carefully work up the labors of his predecessors, and make out their synonymy, is doing far more useful and more honorable labor than he who only affixes his own name to a number of fresh species.

If space and time had permitted, it might have been interesting to have followed up this sketch of the generic forms of Mollusks, with an account of their geographical and geological distribution. But this has been done so admirably by Woodward, in the latter part of his

"Manual of Mollusca," that there is scarcely occasion to do more than to refer the reader to his pages. We have followed the plan of Gray and Adams, of free multiplication of families and genera, rather than that of Woodward of only keeping a few leading distinctions, simply because in the actual work of identifying shells we have found it far more convenient; but a comparison of all ordinary books with the "Manual" only amazes us more and more at the vast amount of patient investigation, of accumulated facts, and of philosophic judgment which its author has condensed into a small volume; and it is equally surprising how, with all the beautiful engravings and woodcuts, it can be sold (as it is in London) for $1 32.

The days are coming when books will be more accessible to students. The contemplated series of text books on American Natural History which the Smithsonian Institution propose to issue will be of essential service. The cheap figures of Chénu will form a portable collection of shells for those who have not access to museums. And to those who cannot obtain even the cheapest of books, there lies, spread out before them, in every stream, in every wood, on every prairie, at every shore, the one grand book of Nature; ever ancient and yet ever new; in which the still small voice of its Life-giver is ever inviting us to come unto Him, and learn; to come unto Him, and labor; to come unto Him, and rejoice in his boundless love.

ALPHABETICAL INDEX.

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